Electronics On The Internet

SILICON CHIP

AUGUST 1996
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AUSTRALIA'S DYNAMIC ELECTRONICS MAGAZINE

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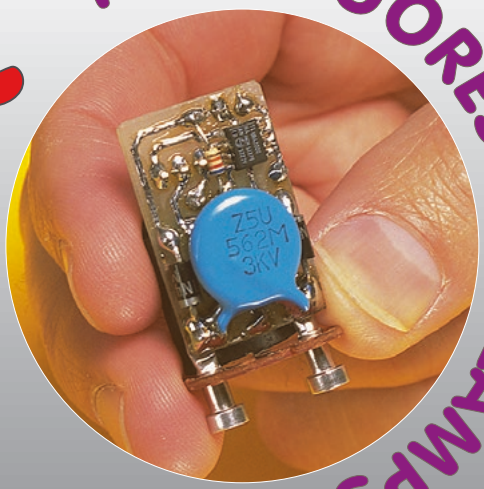
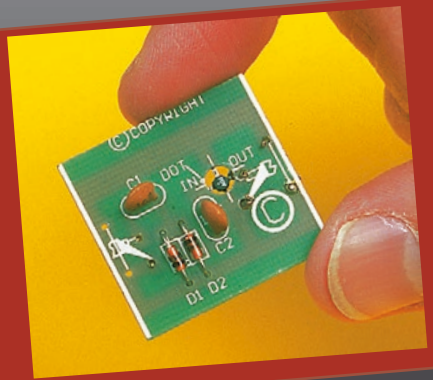
FOR FLUORESCENT LAMPS



350W AUDIO AMPLIFIER MODULE



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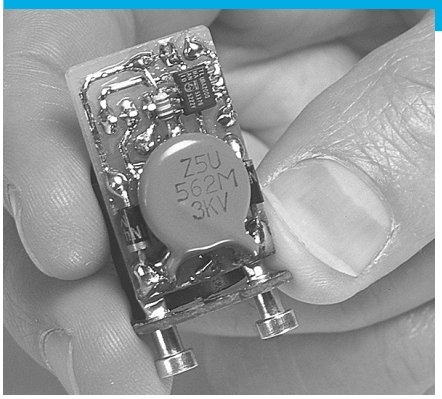

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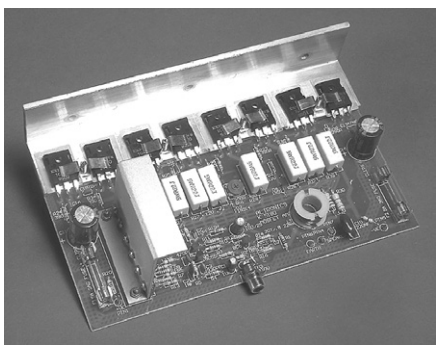

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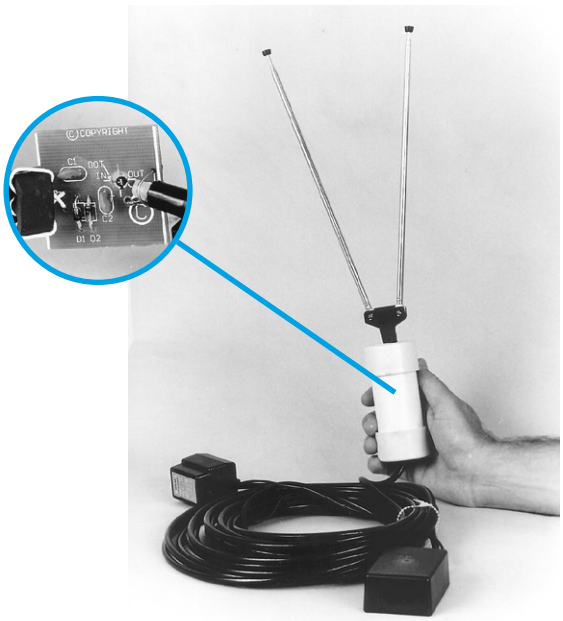

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PUBLISHER'S LETTER

New technology marches on

This month we have a number of articles which help signpost the relentless march of technology. The first of these is the article entitled "Electronics on the Internet" starting on page 4. This gives a glimpse of the huge amount of information pertaining to electronics which is now available on the Internet. Some people are very wary of the hyperbole surrounding the "net" but there is no denying that large numbers of companies, organisations and individuals are becoming involved in it.

Somewhat more prosaic perhaps, is the article on the Electronic Starter for fluorescent lamps, beginning on page 14. The notable point about this circuit is not so much that the integrated circuit at its heart is a clever chip but that it is only available in surface-mount form. Increasingly, many new ICs are only available in this format, so if you don't already have a set of prescription close-up spectacles, it is only a matter of time before you will need them.

Interestingly, if the starter IC had been a conventional 8-pin DIL package it would have been too big. You can expect to see this circuit as a commercial product within a year or so.

On page 30, we are featuring a new high power amplifier module using plastic power Mosfets from England. The point of interest is not that they come from England but that we have probably now seen the last of power transistors or Mosfets in metal TO-3 cans; plastic rules supreme.

On page 64, we have the second article on our VGA Oscilloscope and this highlights the fact that VGA monitors for personal computers, the latest and the greatest in display technology only a few years ago, are now being discarded in large numbers as people upgrade their computers.

While the oscilloscope project is a good application for these otherwise unused and unloved computer monitors, it seems to us that many people are rushing headlong into the purchase of new computers without ever having fully come to grips with the capabilities of their older machines.

Finally, on page 76, we feature an article on IGBTs. These hybrid devices, a marriage between Mosfets and bipolar transistors, first appeared about 10 years ago but have been largely confined to heavy power tasks such as traction motor control. They are gradually making their way into more general use and indeed they were featured in the SILICON CHIP 2kW sinewave inverter in 1992. In the future, you can expect to see them in car ignition systems, in audio amplifiers and in most general power applications.

Leo Simpson

WARNING!

SILICON CHIP magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely. Readers are warned that high voltage wiring should be carried out according to the instructions in the articles. When working on these projects use extreme care to ensure that you do not accidentally come into contact with mains AC voltages or high voltage DC. If you are not confident about working with projects employing mains voltages or other high voltages, you are advised not to attempt work on them. Silicon Chip Publications Pty Ltd disclaims any liability for damages should anyone be killed or injured while working on a project or circuit described in any issue of SILICON CHIP magazine. Devices or circuits described in SILICON CHIP may be covered by patents. SILICON CHIP disclaims any liability for the infringement of such patents by the manufacturing or selling of any such equipment. SILICON CHIP also disclaims any liability for projects which are used in such a way as to infringe relevant government regulations and by-laws.

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FLUORESCENT LIGHT HIGH FREQUENCY BALLASTS

European made, new, "slim line" cased high frequency (HF) electronic ballasts. They feature flicker free starting, extended tube life, improved efficiency, no visual flicker during operation (as high frequency operation), reduced chance of strobing with rotating machinery, generate no audible noise and generate much reduced radio frequency interference compared to conventional ballasts. Some models include a dimming option which requires either an external 100kΩ potentiometer or a 0-10V DC source. Some models require the use of a separate filter choke (with dimensions of 16 x 4 x 3.2cm) - this is supplied where required. We have a limited stock of these and are offering them at fraction of the cost of the parts used in them! Type B: 1 x 16W tube, dimmable, filter used, 43 x 4 x 3cm: **$16.** Type F: 1 x 32W or 36W tube, dimmable, no filter, 34 x 4 x 3cm: **$18**
(Cat G09, specify type).

27MHz RECEIVER CLEARANCE

Soiled 27MHz telemetry receivers. Enclosed in waterproof die cast metal boxes, telescopic antenna supplied. 270 x 145 x 65mm. 2.8kg. Two separate PCBs. Receiver PCB has audio output. Signal filter/squelch PCB is used to detect various tones. Circuit provided: **$12.**

40-CHANNEL FM MICROPHONE

A hand held crystal locked 40-channel FM transmitter with LCD display: 88-92MHz in 100kHz steps, 50m transmission range. Perfect for use with synthesized FM receivers: **$50.**

SPEED CONTROLLED GEARED MOTOR

Experiment with powering small vehicles, large children's cars, garage door openers, electric wheelchairs, rotisseries, etc. etc. We supply a speed control PCB and components kit, A 25A MOSFET and a 30A diode (flyback), and a used 12V geared windscreen wiper motor for a total price of: **$30.**

CHARACTER DISPLAYS

We are offering three types of liquid crystal character displays at bargain prices. The 40 x 2 character display (SED1300F) is similar to the Hitachi 44780 type but is not directly compatible. We will also have similar displays - data available for a 16 x 4 and 32 x 4 display. Any mixture of these displays is available for a crazy price of **$22 each or 4 for $70.**

IR TESTER USING IR CONVERTER TUBE

Convert infra red into visible light with this kit. Useful for testing infra red remote controls and infra red laser diodes. We supply a badly blemished IR converter tube with either 25 or 40mm diameter fibre optically coupled input and output windows and our night vision high voltage power supply kit, which can be powered from a 9V battery. These tubes respond to IR and visible light. A very cheap IR scope could be made with the addition of a suitable casing and objective lens and eyepiece. **$30.**

MISCELLANEOUS ITEMS

2708 EEPROMS: $1 each; 4164 MEMORY ICs: 16 for $10: AC MOTOR, 1RPM Geared 24V-5W Synchronous motor plus a 0.1 to 1RPM driver kit to vary speed, works from 12V DC: **$12 K38 + M30; SPRING REVERB,** 30cm long with three springs: **$30 A10; MICROSONIC MICRO RECORD PLAYER,** Includes amplifier: **$4 A11; LARGE METER MOVEMENTS:** moving iron, 150 x 150mm square face, with mounting hardware: **$10.**

REFLECTIVE TAPE

High quality Mitsubishi brand all weather 50mm wide red reflective tape with self-adhesive backing. Other motorists will see you better at night if this is stuck to chromed or unpainted car bumpers or on bicycles: **3 metres for $5.**

SOUND FOR CCD CAMERAS / UNIVERSAL AMPLIFIER

Uses an LM386 audio amplifier IC and a BC548 pre-amp. Signals picked up from an electret microphone are amplified and drive a speaker. Intended for use for listening to sound in the location of a CCD camera installation, but this kit could also be used as a simple utility amplifier. Very high audio gain (adjustable) makes this unit suitable for use with directional parabolic reflectors etc. PCB: 63 x 37mm: **$10 (K64).**

VHF MODULATOR KIT

For channels 7 and 11 in the VHF TV band. This is designed for use in conjunction with monochrome CCD cameras to give adequate results with a cheap TV. The incoming video simply directly modulates the VHF oscillator. This allows operation with a TV without the necessity of connecting up wires, if not desired, by simply placing the modulator within about 50cm from the TV antenna. Suits PAL and NTSC systems. PCB: 63 x 37mm: **$12 (K63).**

'MIRACLE' ACTIVE AM ANTENNA KIT

Available soon. To be published in EA. After the popularity of our Miracle UHF/VHF antenna kits we have produced this AM version for our 'Miracle' series. Large antennas are not the most attractive inside a house but sometimes this is needed to receive a weak radio signal. This kit will connect to a remote loop of wire, preferably outside where reception is good, via coax cable and allow it to be tuned from inside via varactor diodes. Radio reception is greatly improved and it can even pickup remote stations that a radio can't receive with its ferrite rod antenna. No connections are required to the existing radio as the receiving end is coupled to the ferrite rod in the radio with a loop of wire around the radio. Excellent kit for remote country areas where radio reception isn't very good, or where a large antenna is not possible. Great for caravanners, boats that venture far out to sea, etc. 2 x PCBs and all on-board components.

BATTERY CHARGER WITH MECHANICAL TIMER

Simple kit which is based on a commercial 12 hour mechanical timer switch which sets the battery charging period from 0 to 12 hrs. Employs a power transistor and five additional components. Can easily be "hard wired". Information that shows how to select the charging current is included. We supply information, circuit and wiring diagram, a hobby box with aluminium cover that doubles up as a heatsink, a timer switch with knob, a power transistor and a few other small components to give you a wide selection of charge current. You will also need a DC supply with an output voltage which is greater by about 2V than the highest battery voltage you need to charge. As an example a cheap standard car battery charger could be used as the power source to charge any chargeable battery with a voltage range of 0-15V. Or you could use it in your car. No current is drawn at the end of the charging period: **$15.**

AUTOMATIC LASER LIGHT SHOW KIT

Kit as published in Silicon Chip May 96 issue. The display changes every 5 - 60 seconds, and the time is manually adjustable. For each of the new displays there are 8 different possible speeds for each of the 3 motors, one of the motors can be reversed in rotation direction, and one of the motors can be stopped. There are countless possible interesting displays which vary from single to multiple flowers, collapsing circles, rotating single and multiple ellipses, stars, etc. etc. Kit makes an excellent addition to any lightshow and all these patterns are enhanced by the use of a fog machine. Kit includes PCB, all on board components, three small DC motors, 3 high quality/low loss dichroic mirrors: **$90.** Suitable 12V DC plugpack: $14.

LASER LIGHTSHOW PACKAGE

Our 12V Universal inverter kit plus a used 5mW+ helium-neon laser tube head plus a used Wang power supply plus an automatic laser light show kit with dichroic mirrors (as above): **$200.**

ARGON-ION HEADS

Used Argon - Ion heads with 30-100mW output in the blue - green spectrum. Head only supplied. Needs 3Vac @ 15A for the filament and approx 100Vdc @ 10A into the driver circuitry that is built into the head. We provide a circuit for a suitable power supply the main cost of which is for the large transformer required: $170 from the mentioned supplier. Basic information on power supply provided. Dimensions: 35 x 16 x 16cm. Weight: 5.9kg. 1 year guarantee on head. Price graded according to hours on the hour meter: We have had no serious problems with any of these heads as they were used at a very low current in their original application. Argon heads only: **$300.**

SIREN USING SPEAKER

Uses the same siren driver circuit as in the "Protect anything alarm kit". 4-inch cone / 8-ohm speaker is included. Generates a very loud and irritating sound with penetrating high and low frequency components. Output has frequency components between 500Hz and 4kHz. Current consumption is about 0.5A at 12V. PCB: 46 x 40mm. As a bonus, we include all the extra PCBs as used in the "Protect anything alarm kit": **$12.**

DC MOTORS

We have good stocks of the following high quality DC motors. These should suit many industrial, hobby, robotics and other applications. Types: Type M9 : 12V. I no load = 0.52A @ 15800 RPM at 12V. Weight: 150g. Main body is 36mm diameter. 67mm long: $7 (Cat M9) Type M14 : Made for slot cars. 4 to 8V. I no load = 0.84A at 6V. At max. efficiency I = 5.7A @ 7500 RPM. Weight: 220g. Main body diameter is 30mm. 57mm long: **$7 (Cat M14).**

ULTRASONIC COMMUNICATOR KIT

Ref: EA Sep/Oct 93. Signals picked up by an electret microphone are modulated onto an oscillator which drives a 40kHz ultrasonic transducer. This is received by a 40kHz ultrasonic receiving transducer and is amplified and detected. The detected signal is amplified by a simple three transistor amplifier to drive a speaker. This makes a communications link using ultrasound which can transmit over a few metres. The quality of the sound is limited by the narrow bandwidth of the transducers but this is an interesting experiment. Both transmitter and receiver PCBs are 63 x 33mm: **$16 (K45).**

BOG DEPTH SOUNDER KIT

Detect the presence and depth of any body filler on your car. This simple circuit uses an oscillator which is oscillating weakly. When steel is placed near the small search coil the inductance shifts and the oscillator components are arranged so the oscillator will stop running. The remainder of the circuit simply detects when the oscillator stops and gives a visual or audible indication of this. The circuit is arranged so that the change in inductance needed to stop the oscillator can be varied. This allows variable depth of filler sensing, between 0 and about 3mm. Large areas of body filler over 3mm thick are generally considered undesirable as the filler may lift or crack. Kit supplied includes pre-wound search coil (33 x 22 x 10mm). A LED is supplied in the kit as the visual indication. An audible indication can be obtained by using a low power piezo buzzer, which is recommended but not supplied with the kit: **$12 (K62).**
$2 for optional low power piezo buzzer.

HIGH VOLTAGE AC DRIVER

This kit produces a high frequency high voltage AC output that is suitable for ionizing most gas filled tubes up to 1.2m long. It will partially light standard fluorescent tubes up to 1.2m long with just 2 connections being made, and produce useful white light output whilst drawing less than 200mA from a 12V battery. Great for experimenting with energy efficient lighting and high voltage gas ionization. PCB plus all on board components, including high voltage transformer: **$18.**

PC CONTROLLED PROGRAMMABLE POWER SWITCH MODULE

This module is a four-channel programmable on/off timer switch for high power relays. The timer software application is included with the module. Using this software the operator can program the on/off status of four independent devices in a period of a week within a resolution of 10 minutes. The module can be controlled through the Centronics or RS232 port. The computer is opto-isolated from the unit. Although the high power relays included are designed for 240V operation, they have not been approved by the electrical authorities for attachment to the mains. Main module: 146 x 53 x 40mm. Display panel: 146 x 15mm. We supply: two fully assembled and tested PCBs (main plus control panel), four relays (each with 3 x 10A / 240V AC relay contacts), and software on 3.5-inch disk. We do not supply a casing or front panels: **$92 (Cat G20).**

ELECTRONICS ON THE INTERNET

There's a wealth of information on the Internet for electronics designers and engineers. You can check data sheets on the latest devices, order parts or even market your products via the World Wide Web.

By SAMMY ISREB

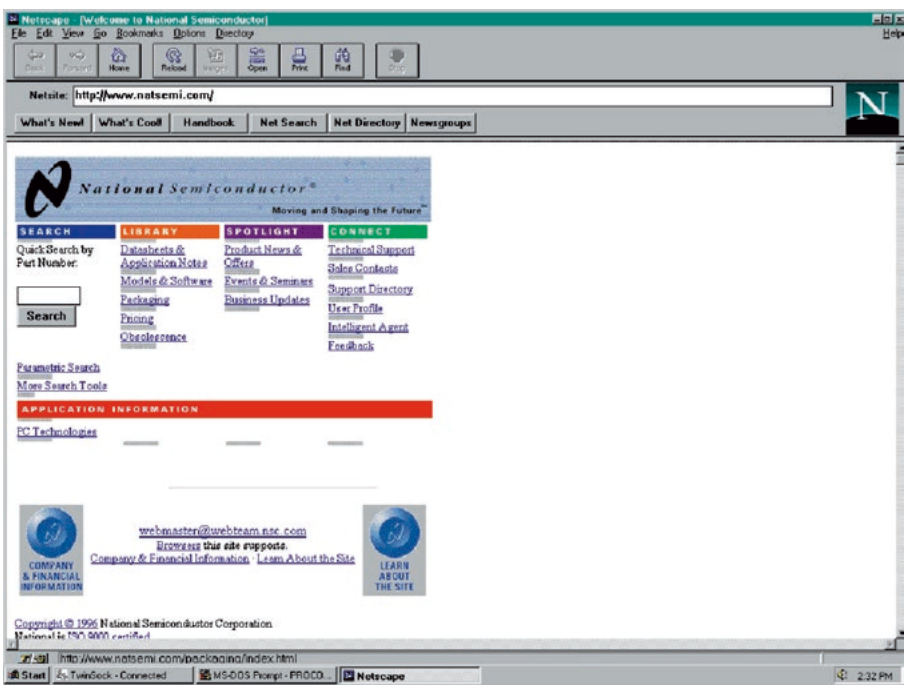


Fig.1: the National Semiconductor homepage screen. Among other things, it allows the user to search for a component by part number, to browse a library of datasheets and to seek out technical advice and sales information.

Before you turn the page thinking that this is just another Internet article WAIT! It has no resemblance to the myriad of articles on how to get onto the Internet and use it. In fact, before you can use any of the information in this article you have to be already "hooked up" to the Internet and be familiar with its use.

So now that we know what this article is not about it is time to explain what it is about. The Internet contains hundreds of web sites and news groups that are dedicated to electronics. The news groups are made up chiefly of support or help groups, while the web sites are usually commercially orientated.

Web sites

Many electronic companies have embraced the World Wide Web with open arms, setting up their own home pages. The most valuable web sites for designing circuits are those of the IC manufacturers. Many companies include datasheets on all ICs that they manufacture, as well as application circuits and pricing and availability data. Some web sites, such as National Semiconductor's, even allow the user to search for a device name and/or number to find a datasheet for an unknown device.

This service is very handy when you have an unknown IC and want to get more information on it. All datasheets and application notes are in the *.pdf format and require a reader such as Adobe Acrobat Reader Ver. 2.1 or later.

This software can be downloaded from the National Semiconductor or Adobe web sites. It will be compressed in the pkzip format and is easily ex-

panded using any pkunzip compatible archiving utility.

A feature of some IC manufacturer web sites, such as the Motorola Semiconductor site, is a fax back feature. With this, the user can request that a datasheet be faxed to his/her fax machine by simply selecting the datasheet required and entering the phone number. Failing this, some web sites offer a "snail mail" service which allows the selected information to be mailed to the address entered at the prompt.

With the microcontroller industry booming, the Internet can be the best way to select a family of chips to use. Most manufacturers are represented on the Internet. This allows easy comparison with opposition systems so that the one that best suits your needs can be selected. After browsing the Parallax web site, I decided that their Basic Stamp looked like a fun toy and ordered one. Be warned – lock away your wallet before browsing web pages!

As well as the microcontroller sites that are run by the manufacturers, there are quite a few sites that are conducted by electronics enthusiasts who have fallen "in love" with a particular type of microcontroller. These sites usually have a deluge of circuits using the microcontroller in question, with some of the circuits being quite novel and ingenious.

Probably the best feature of these sites, however, is that their owners are usually happy to answer any questions/problems relating to their particular microcontroller. Links to the best of these sites are sometimes also included in the manufacturer's sites.

Circuit databases

There are also many web sites and ftp (file transfer protocol) servers which contain databases of small circuits, along with short descriptions. Many of these circuits are quite novel, while some are downright strange in their uses of standard components. The sites also contain the standard boring building block circuits such as two trillion uses for a 555 timer and so forth.

Along with such sites, which are usually operated by universities or electronics enthusiasts, are similar sites run by commercial companies, or for commercial companies by workers or private enthusiasts. The Parallax ftp site contains quite a few circuits using their microcontrollers, as well as links to similar sites.

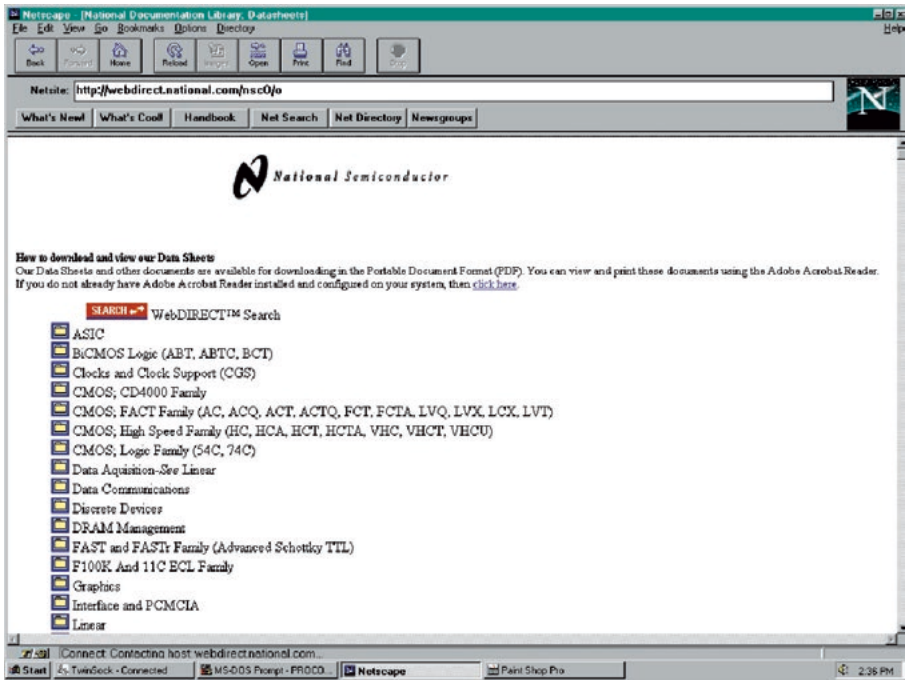


Fig.2: the National Semiconductor IC data page menu. You can download selected information and even download the Adobe Acrobat reader if you don't already have a copy.

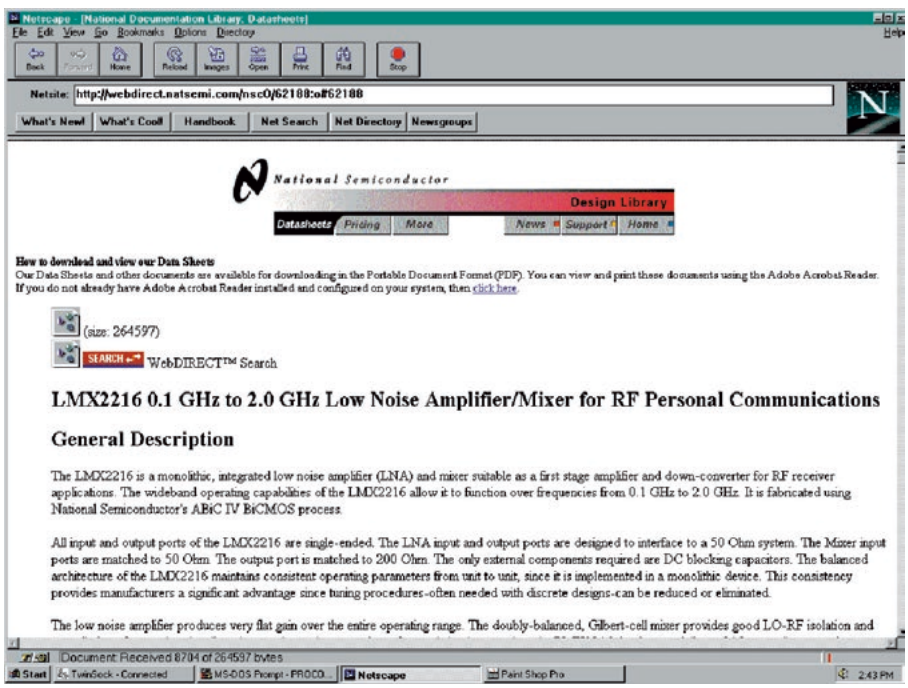


Fig.3: this National Semiconductor data page shows information on the LMX2216 low-noise amplifier/mixer IC. Clicking on the download icon allows the datasheet to be downloaded.

Shareware

Electronic related shareware is available freely on the Internet. Indeed, many ftp and web sites dedicated to electronics will have several directories containing useful programs. These are usually split into various categories such as PC board design and manufacture, schematic plotting and CAD programs, simulation programs of various types, and educational files. All of these files will be archived in

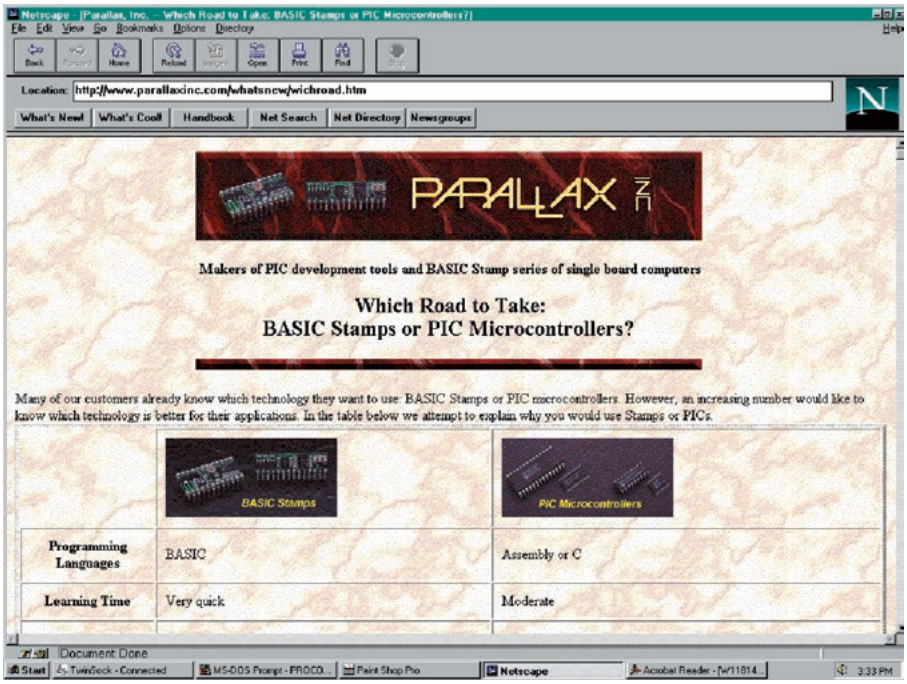


Fig.4: the Parallax homepage. It offers information on the Basic Stamp and PIC microcontrollers, includes quite a few circuits, and has links to various other sites that offer circuits.

some way and can be downloaded in the standard fashion.

As well as these shareware programs, many commercial software manufacturers place demonstration packages of their software on web/ftp sites. This type of software is usually either a "crippled" version of the real thing or a much older superseded version.

In either case, this software is good enough for demonstration purposes and gives the user the opportunity to "try before buying".

Mail order stores

As the Internet's popularity increases, many mail order electronics stores are setting up web sites on which users can browse their goods catalog and even select, order and pay for their goods. While this trend is a bit sluggish taking off in Australia, there are many electronics dealers overseas who sell goods via the World Wide Web.

The fact that a price for the same component can be obtained from dozens of shops from around the world in a few minutes really allows for customers to come out on top.

A tip to buying goods is to know what you are looking for from the outset and do a web search on the item. If you are uncomfortable giving credit card details to an unknown company halfway around the world, send them a cheque by "snail mail" instead.

It is also now possible to consult with several PC board design and production companies on the web. Whilst these business transactions can't be carried out fully online, it is possible to get some idea of what the various companies have to offer, what type of pricing to expect, and previous examples of their work.

Marketing

Once your perfect circuit is up and running, the Internet is a great way to get it onto the market. It is possible to obtain quotes on various components in high quantities from specialist wholesale dealers and you can even try negotiating a deal to supply the finished product to one of the web's electronics dealers. An alternative to this is to set up your own web site to advertise your products.

If you do decide that your own web page is the way to go, a good way to increase the number of hits it receives is to convince an established electronics web site to include your site as one of its links.

News groups

Those who encounter a brick wall when designing or repairing a circuit should try the electronics news groups. A search of "electronics" will give a list of several different news groups dedicated to divergent disciplines of electronics. Make sure that the one you select is the relevant one for your problem, as not doing so can make the users of the newsgroup you mail quite irate.

After selecting the appropriate news group, post a letter stating your problem clearly. Be sure to include your email address so that the solution

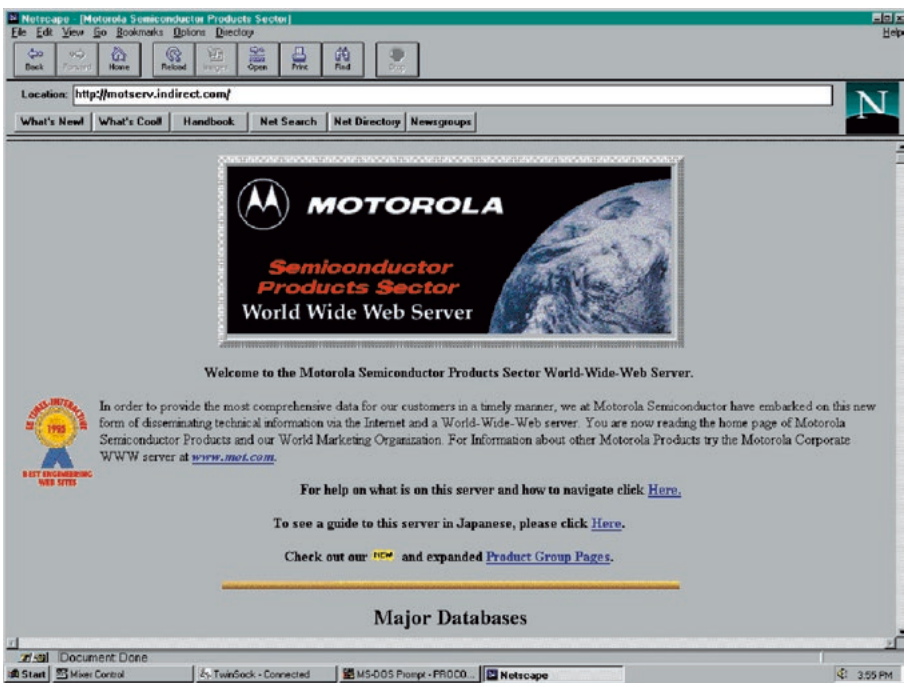


Fig.5: the Motorola Semiconductor Products homepage. A feature of the Motorola site is a fax-back facilitity.

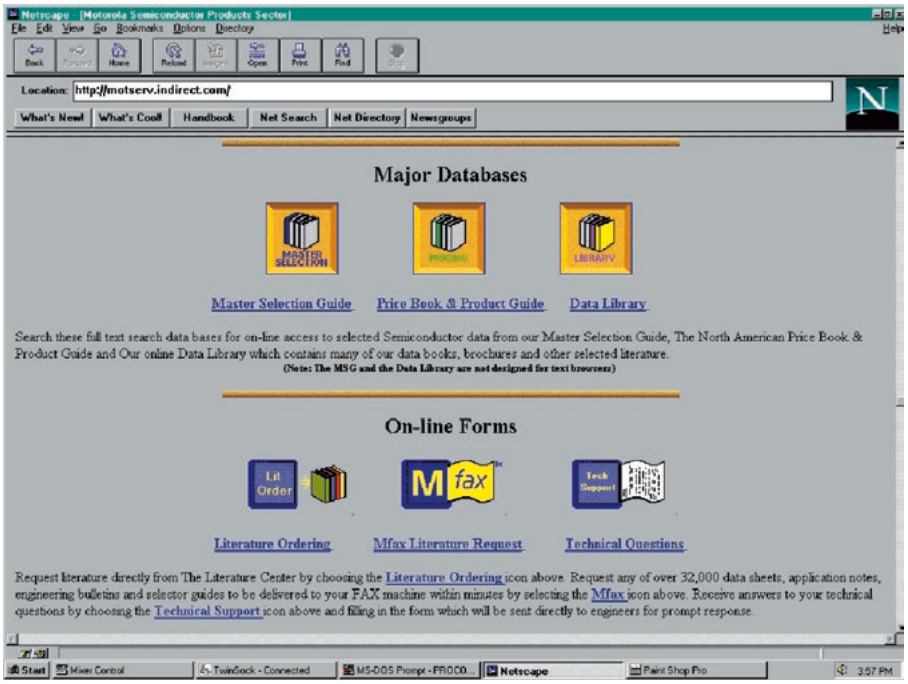


Fig.6: this screen shows the Motorola datasheet page. You can ask questions by clicking the Tech Support icon and then filling in the on-screen form.

to your problem can be forwarded to you. After posting your problem, read through a few other people's problems and try to solve them as this keeps the news groups going.

Although the advice given on news groups is very helpful, with many electronic professionals giving advice, the advice given should never be taken as gospel. Also, while most conversations that go on in the news groups deal with standard electronic problems and can be very educational, readers should be very wary of some of the topics discussed.

On the day I accessed the news groups to research this article, 10 of the postings dealt with a person who wanted to construct a 1,000,000V tesla coil in his garage after seeing a tesla coil on a television science show. Most of the advice told him not to attempt it if he valued his life, as it was not the type of experiment to be attempted by a beginner.

Another 18 postings dealt with a student who wanted information on constructing an electromagnetic gun to fire metal stakes!

Related sites

As well as the resources described above, there are many web sits and news groups that deal with the electronics aspects of various hobbies. Model rocketry, a hobby of mine, is quite well supported, with web pages containing information on the electronics involved. There is also a model rocketry newsgroup where problems are quickly solved or, if necessary, forwarded to one of the electronics news groups.

Other hobbies that are supported include radio controlled models and model trains. **SC**

Web sites To Try

The web sites listed below are among my favourites and are invaluable for any electronics work. Note, however, that they represent just a tiny fraction of the web sites that deal with electronics – there are thousands of others.

http://www.hitechsurplus.com/
High-tech surplus goods for sale from North America

http://www.natsemi.com/
National Semiconductor homepage

http://www.parallaxinc.com/
Parallax homepage

http://www.hutch.com.au/~oz-tech/oztech.htm
Oztechnics homepage

http://motserv.indirect.com/
Mototola homepage

http://www.mot.com
Motorola corporate homepage

http://www.ee.ualberta.ca/html/cookbook.html
Electronic cookbook Archive

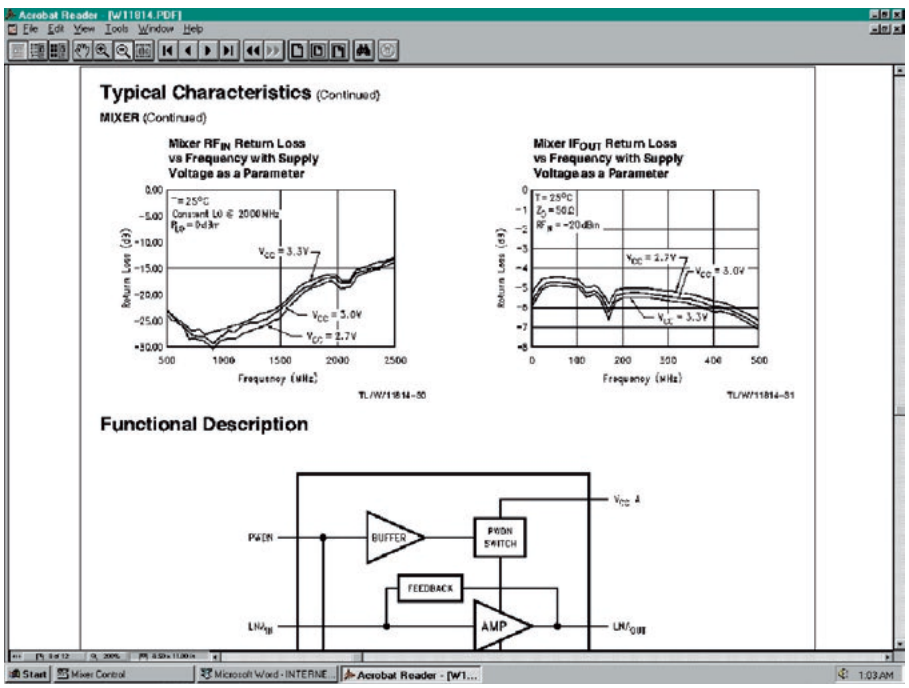
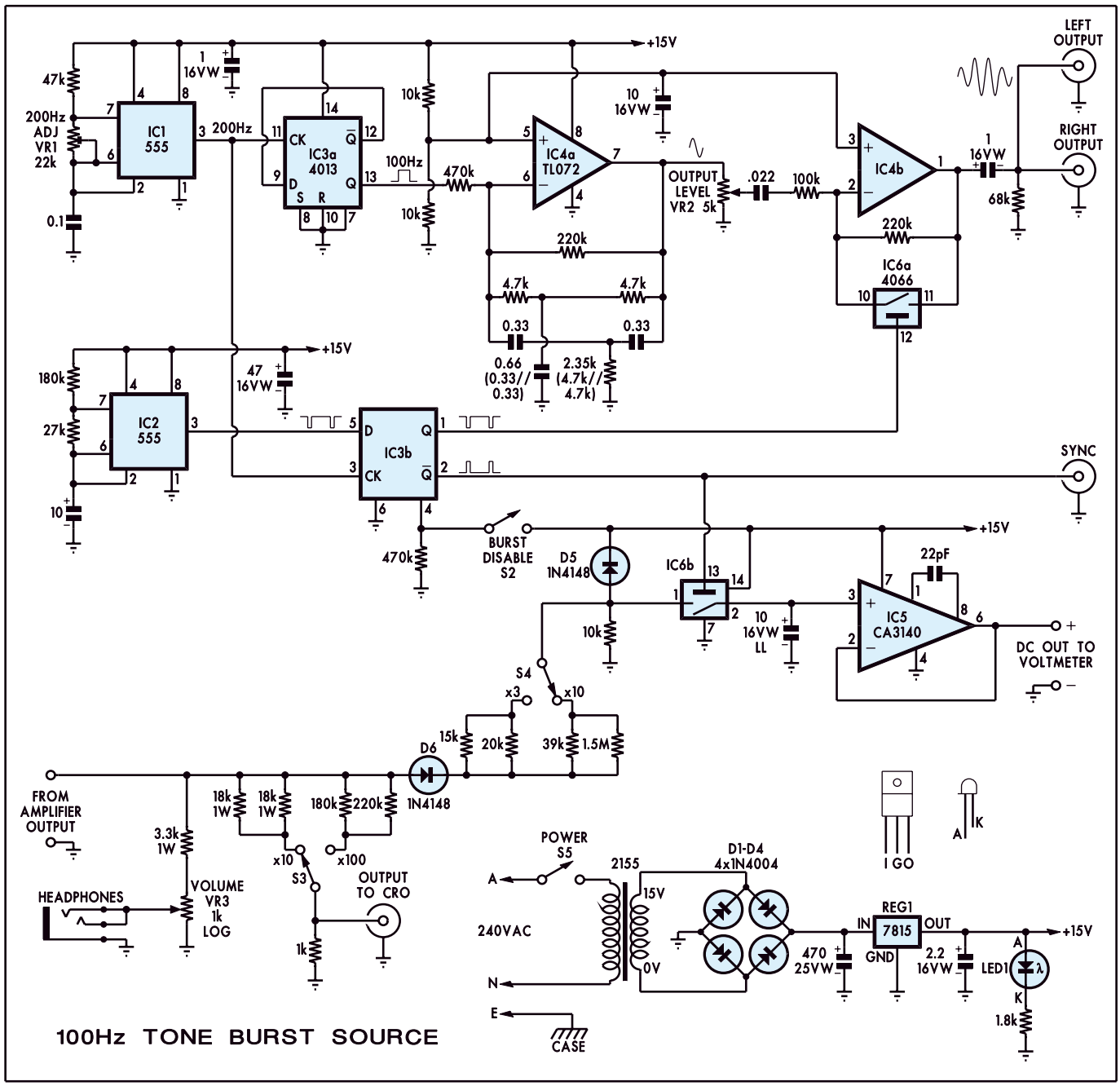


Fig.7: Adobe's Acrobat reader is being used here to display the datasheet on the National Semiconductor LMX2216 0.1-2GHz low noise amplifier/mixer.

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions from readers are welcome and will be paid for at standard rates.



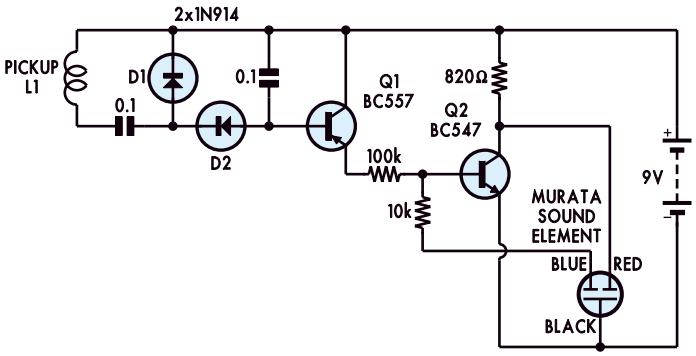
Tone burst source for loudspeaker testing

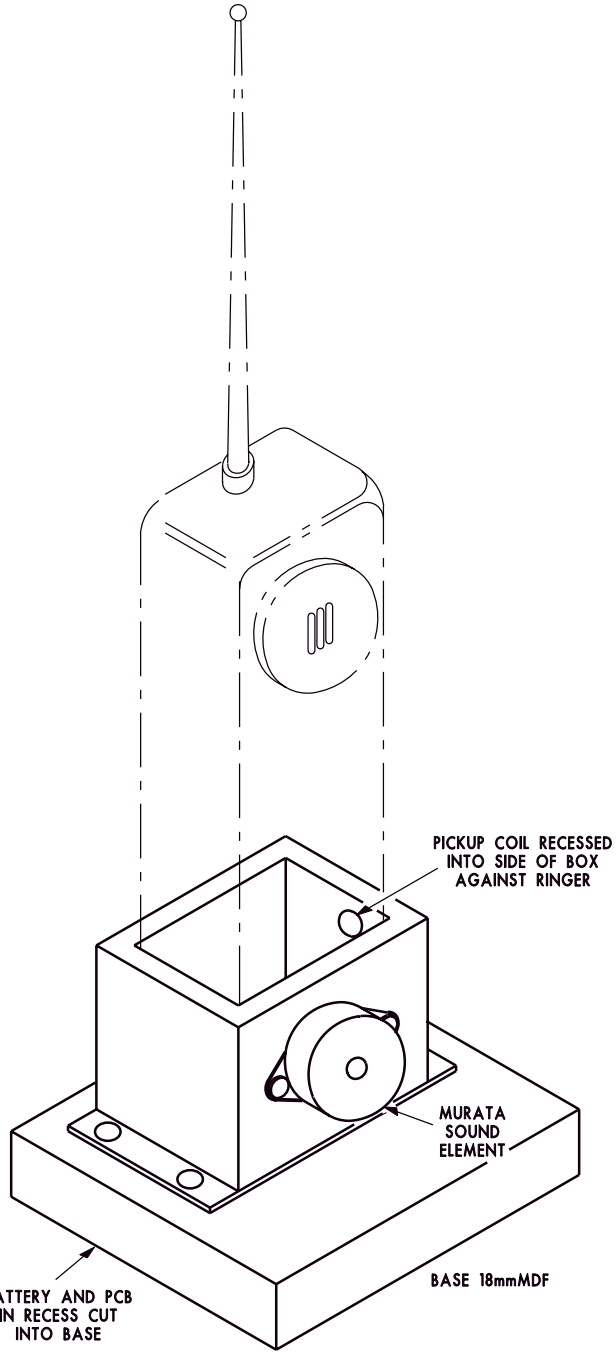
Testing loudspeakers for maximum power handling can be difficult if only a continuous tone is available. This is because the sound level is likely to be excessive before the distortion becomes obvious. Also it is not a realistic test since music sources are rarely continuous tones.

A tone burst signal can provide a more valid test since it produces a high level signal for a small time, consistent with typical program material. The tone burst source presented here will produce a 100Hz tone for 200ms every 1.4 seconds. The output level is adjustable and connects to a power amplifier in order to drive the loudspeaker into overload.

Measuring the power level at overload is made simple by the addition of a sampling circuit which monitors

Cordless telephone ring tone booster





The circuit uses a pickup coil to detect variations in the magnetic field generated in the vicinity of the ringer. The view at right shows the suggested mounting arrangement for the handpiece.

Many cordless telephones have a very feeble ring tone, especially if one is challenged in the hearing department. While the audio output may be weak, a significant magnetic field is generated in the vicinity of the ringer and this can be used to trigger a booster.

This device uses a Murata Sound Element (Cat. AB-3444 from Jaycar) as the sound generator. The pick-up coil consists of 800-1000 turns of 34 B&S (0.16mm) wire on a 20mm diameter former, 5mm wide and with a 5mm centre. A slug from a discarded IF transformer will enhance sensitivity but is not vital.

Diodes D1 and D2 and the capacitors form a voltage doubler to turn on Q1 when a ring signal is detected. This, in turn, supplies positive bias to Q2, enabling the sound element.

The circuit draws negligible standing current and only 5mA when ringing so that battery life should approximate shelf life.

The hard part of construction is the support for the handpiece (which will vary from model to model) to hold the coil close to the ringer. The sketch shows one possibility. The battery and PC board are mounted in the hollowed out base.

A. March,
North Turramurra, NSW. ($30)

---

the signal during the tone burst. The resulting signal is output as a DC voltage which can be read using a standard multimeter. The power delivered to the loudspeaker is simply calculated by squaring the measured DC voltage and dividing by the impedance of the loudspeaker (2, 4 or 8Ω).

The circuit is based on the IHF Tone Burst Source published in July 1988. A 200Hz signal is produced by 555 timer IC1 which is divided by two in D-flipflop IC3a. This gives a 100Hz square wave. IC4a is connected as a bandpass filter to reject signals other than the 100Hz fundamental and the output is thus a sinewave. VR2 adjusts the signal level applied to IC4b.

Normally, with switch IC6a closed, there is very little 100Hz signal at the pin 1 output of IC4b. When the switch opens, IC4b has a gain of 2.2 and the signal level is high.

IC2 sets the burst rate and duration. The pin 3 output controls the data input of D-flipflop IC3b. Its high output time is set by the 180kΩ and 27kΩ resistors plus the 10µF capacitor. The low output time is set by the 27kΩ resistor. Each time IC3b is clocked by the 200Hz signal, the Q output follows the data input which in turn controls switch IC6a.

The amplifier output is monitored and rectified by diode D6. The signal is then divided by the attenuator set by the resistors at switch S4. IC6b allows the signal to pass to a 10µF capacitor during the burst period and it is controlled by the Q-bar output of IC3b. IC5 buffers the voltage applied to the 10µF capacitor and holds the voltage level when the tone burst is off.

Power is derived from a 15V transformer. D1-D4 rectify the AC, while a 7815 regulator provides the circuit with a 15V supply.

SILICON CHIP.

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dicksmith.com.au

Clever IC provides rapid turn-on

ELECTRONIC STARTER

For fluorescent lamps

Do your fluorescent lamps go *blinkety-blink blink blink* when you turn them on? Or do they flash on to blind you and then plunge you into darkness? Solve these problems with this new electronic starter which gives a rapid start every time. It fits in a standard starter case so the lamp wiring does not have to be altered.

By JOHN CLARKE

LET'S FACE IT, fluorescent lights are bright and efficient but they can be very annoying when they don't start as soon as you switch them on. This "blink blink blink - nothing - flash - Ah! it's on!" sequence can be particularly frustrating if you need to leave your warm bed on a cold night for a "comfort break". Fluorescent lamps are much harder to start when the temperature is low which adds to the problem.

What can be really frustrating if you have a cantankerous fluorescent lamp is that changing to a new starter or even a new tube may not help much. Modern slimline 18W and 36W tubes are hard to start, even when new, and they are a real problem if they are used in a batten fitting intended for older style 20W or 40W tubes.

Up till now, there has been no solution to this problem but Philips has just released a surface mount 8-pin chip which appears to be a real ripper. Designated the UBA2000T, it is specifically designed to start slimline "TL" tubes and incorporates features which overcome all the disadvantages of conventional "glow switch" fluorescent starters.

Before delving into the operation of the electronic starter we need to see how a fluorescent lamp circuit works and why the conventional starter it has its disadvantages. So let's refer to Fig.1.

A fluorescent lamp is connected to the 240VAC mains supply via a "ballast" which is an iron cored inductor. In more detail, the current from the 50Hz mains passes through one of the tube filaments, then through the starter, through the other filament and then via the ballast. The starter, as its name implies, gets it all going.

If you pull a conventional starter apart, and you will if you build this project, you will find that it contains what looks like a conventional miniature neon lamp connected in parallel with a high voltage capacitor, typically .005µF 2kV ceramic disc. This very simple construction has quite a complex function. Similarly, the fluorescent tube itself looks very simple but there is more to it than meets the eye.

A fluorescent tube is coated with a phosphor on the inside of the glass and it contains a minute quantity of mercury and a mixture of inert gases. As well, it has a filament heater at each end.

This made with triple coiled tungsten wire and coated with an emissive material such as barium or strontium oxide. When power is first applied to the circuit of Fig.1, current is passed through the two filaments to raise them to red heat and this causes them to emit electrons, just like the filament in a radio valve. The electrons rapidly disperse along the tube so that when a high voltage is applied to the tube, an electric discharge can occur through the inert gases.

Once this discharge starts, the mercury in the tube is vaporised and it begins to emit ultraviolet light. The ultraviolet causes the tube phosphors to fluoresce and so visible light is produced.

The job of the starter is twofold. First, it has to let current pass through the filaments so they can heat up and emit electrons. Then after a short delay, the starter interrupts the current to the filaments. Since the ballast inductor is also in series with the filaments, this sudden interruption of current causes it to produce a brief high voltage spike. This high voltage is applied to the tube to cause the electric discharge referred to above. If all goes well, the tube lights up and then the starter is effectively out of circuit.

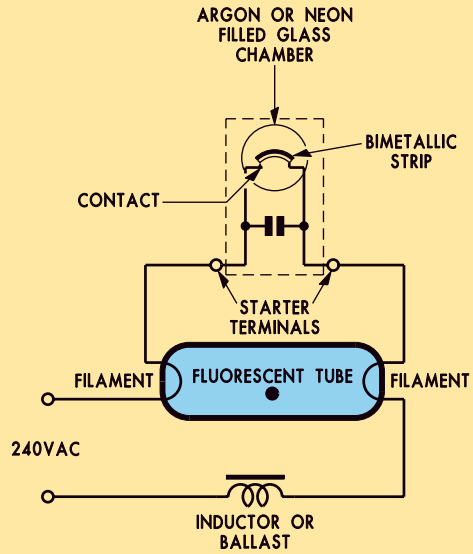


Fig.1: the circuit a conventional fluorescent lamp with a glow switch starter. The starter enables filament current to flow at switch-on and it opens after a short delay. The back-EMF then generated by the ballast inductor then fires the tube. That's the theory anyway.

Clearly though, while the glass tube in the fluorescent starter might just look like a largish neon lamp, it is more than that. The starter has two contacts, one of which is bimetallic. When voltage is first applied to the circuit of Fig.1, the inert gas inside the starter ionises and a small amount of current flows. This heats up the interior of the starter and so the bimetallic contact bends over slightly to meet its mate and so current can flow through the two filaments and the ballast.

Meanwhile the interior of the starter cools down, the bimetallic contact opens the circuit, the filament current stops and the ballast fires the tube. If all goes well, that is. Generally though, the starter has to make several tries before the fluorescent tube fires properly and that leads to the blink, blink problem that we all know and hate.

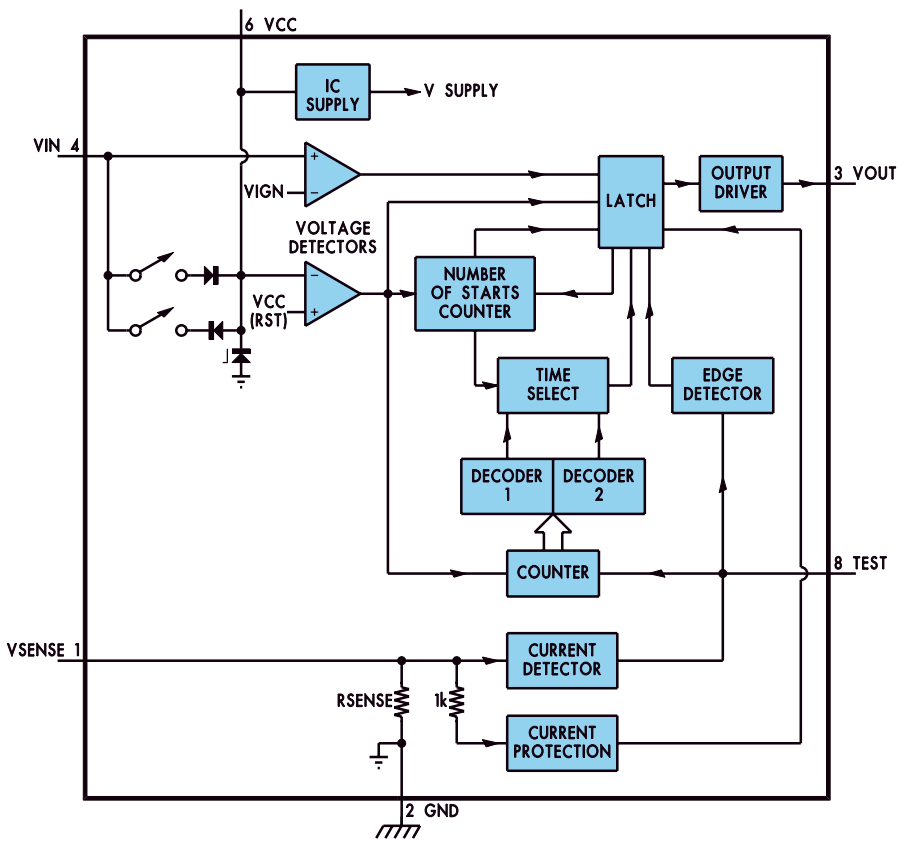


Fig.2: functional diagram of the UBA2000T TL lamp starter. It counts the cycles of the 50Hz supply to give a precise filament heating time and it also monitors filament current to ensure that the lamp has the best chance of starting.

Features

- Starts 18 and 36W slimline fluorescent tubes
- Compatible with standard fluorescent starters
- Fast start without excessive flicker
- Precise preheat time
- Minimal radio interference
- Timeout if lamp fails to fire

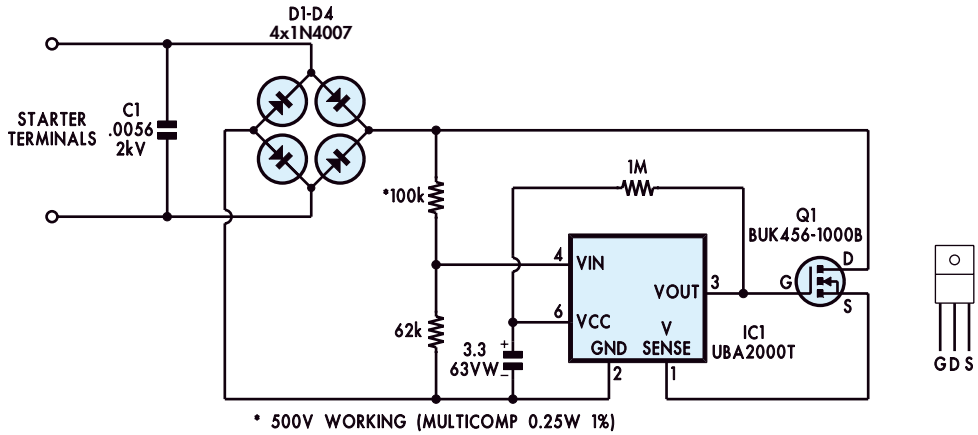


Fig.3: the UBA2000T lamp starter IC (IC1) switches a 1000V Mosfet (Q1) to reliably start slimline and conventional fluorescent tubes. The IC repeats the start sequence up to six times, after which the Mosfet is turned off as a safety measure.

ELECTRONIC FLUORESCENT TUBE STARTER

So why is the capacitor inside the starter? One reason is that it helps prevent arcing across the contacts as they open. The other is that it helps reduce the radio interference both from the starting operation and from the electric discharge inside the fluorescent tube.

These conventional starters are very simple to manufacture but they have a number of drawbacks. First, the preheat time is set by the thermal lag of the bimetallic contact. This is the time it takes the contact to cool and reopen and it can vary depending on ambient temperature and manufacturing tolerances. In some cases the preheat time will not be enough to allow the filaments to warm up sufficiently to fire the tube. Naturally, this problem gets worse as the starter and fluorescent tube get older.

A more serious problem is that when the starter contact opens, the induced voltage from the ballast may not be sufficient to fire the tube. This is because the bimetallic contact can open at any time within the mains cycle and the ballast current may be very low when this happens. So that is why even a new starter may need several tries to fire the fluoro tube.

PARTS LIST

1 PC board coded 10308961, 17 x 28mm
1 fluorescent starter container and lid with terminals (see text)
1 12mm diameter x 12mm long piece of heatshrink tubing

Semiconductors
1 UBA2000T TL-lamp starter (IC1) (Philips)
1 TO-220 1000V Mosfet, BUK456-1000B, STP3N-100 (Q1)
4 1N4007 1000V rectifier diodes (D1-D4)

Capacitors
1 3.3µF 63VW PC electrolytic
1 .0056µF 2kV ceramic

Resistors (0.25W, 1%)
1 1MΩ
1 100kΩ 500V MAX (Multicorp)
1 62kΩ

Thirdly, there is no provision to stop the starter sequence if the lamp fails to start. This repetitive starting can eventually burn out the ballast due to overheating. Alternatively, if the starter's contacts weld up, the ballast will be burnt out and this means an expensive repair. Generally, it is cheaper to replace the whole lamp fitting.

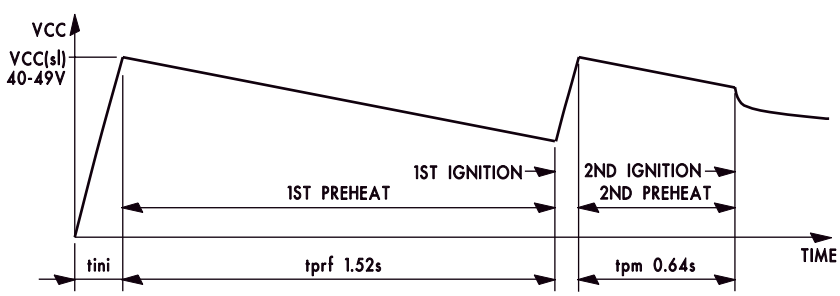


Fig.4: this diagram illustrates the starting sequence of the UBA2000T.

Clever chip

Our new electronic starter circuit is shown in Fig.2. It plugs in directly to the starter socket on a fluorescent lamp fitting. As well as using the Philips UBA2000T lamp starter chip, it has a 1000V Mosfet, a bridge rectifier and a few resistors and capacitors. While the UBA2000T is a teensy little chip, it has quite a lot of circuitry inside it, as indicated by the functional diagram of Fig.2.

Looking at Fig.2, the UBA2000T has V_{in} and V_{sense} pins which monitor the mains voltage and filament current, respectively. By monitoring V_{in} the UBA2000T knows whether the tube is ignited or not; the voltage level is lower once the tube is ignited. By monitoring the filament current, the UBA2000T can fire the tube at the optimum time.

Pin 3 drives the gate of a 1000V Mosfet which is used to switch the filament current on and off. The Mosfet is not switched on if the Vcc supply is too low (below 40-49V) or the current through the filaments is excessive (above 2.2A peak).

Fig.4 shows the typical start sequence waveform. When power is first applied to the circuit, the capacitor at the Vcc pin is charged through the internal switch S1. When Vcc reaches the start voltage, (Vcc(sl)) and when the mains voltage is at its peak value, the Mosfet will be turned on.

The UBA2000T now counts the mains cycles until 1.52 seconds (ie, 76 cycles at 50Hz) has elapsed. Also during this time the capacitor at the Vcc pin discharges. The Mosfet is switched off provided the current through the internal sense resistor is greater than 285mA. This allows the ballast inductor to produce sufficient voltage to fire the tube. Typically, this firing voltage will be somewhere between 700 and 800V!

If the fluorescent tube does not fire, the UBA2000T tries again, as shown in Fig.4. It must first recharge its own supply capacitor at pin 6 (V_{CC}) and then filament current is applied again. This second preheat period is set to 0.64s since the filaments are already assumed to be warm.

After the tube fires, the peak voltage across it will typically be about 100V which is considerably lower than the mains voltage peak (around 340V) and so the Vcc(sl) threshold for the UBA2000T can no longer be reached. The Mosfet is therefore held off and the starter circuit is effectively out of action until the mains voltage is turned off and reapplied.

The UBA2000T will repeat the start sequence six times after which the Mosfet will be turned off. This is a very good safety feature since it prevents the ballast inductor from being burned out. As a further safety feature, the Mosfet will be turned off if the sensed preheat current exceeds 2.2 amps peak.

Circuit description

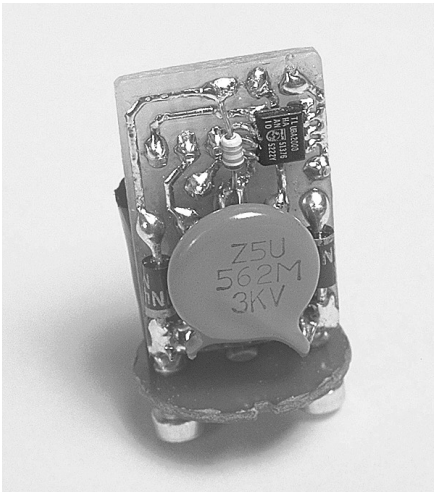
The circuit of Fig.3 shows how the UBA2000T is used in practice. Diodes D1-D4 are connected in a bridge to rectify the mains voltage. This applies the correct voltage polarity to both IC1 and Q1.

The 100kΩ and 62kΩ resistors across this rectified mains supply divide the voltage down for the pin 4 input and limit the charge current to the 3.3µF Vcc capacitor at pin 6.

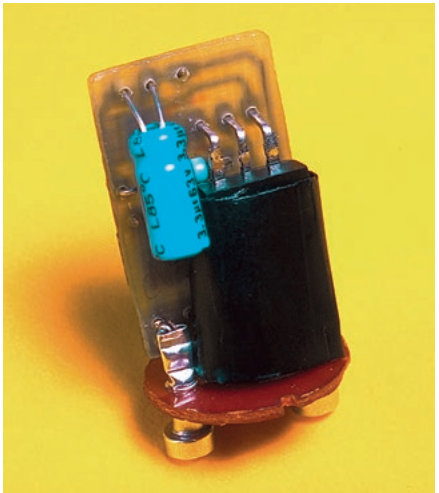
The 1MΩ resistor between pin 6 and the gate of Q1 provides a small pullup current to keep the Mosfet gate high once it is triggered by a pulse from pin 3. The gate is switched off when pin 3 goes low. Note that the source electrode of the Mosfet is connected to pin 1 so that its current (ie, the filament current) is sensed by the internal 26mΩ resistor between pins 1 and 2 of IC1.

Capacitor C1 is included to suppress radio frequency interference caused by discharge in the tube.

Note that all components are rated for the high voltages involved. The 3.3µF 63VW capacitor can have up to 49V across it, while the voltage across the tube at the instant Q1 is switched off can be 800V or more. Consequently, C1 has a 2kV rating while Q1 and D1-D4 have a voltage rating of 1kV. The 100kΩ resistor must have a minimum rating of 500V.



This photo shows the copper side of the assembled PC board. The surface mount IC means that you will need a fine-tipped soldering iron to mount it in place.



Only three parts are mounted on this side, the main one being the 1000V Mosfet. This should be sleeved with heatshrink tubing before the board is installed inside the starter case.

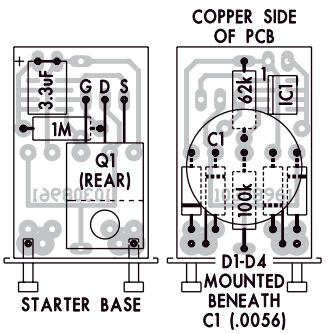


Fig.5: the parts layout diagrams for both sides of the PC board. Note that the four diodes and the 100kΩ resistor are mounted underneath the .0056µF ceramic capacitor.

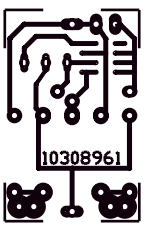


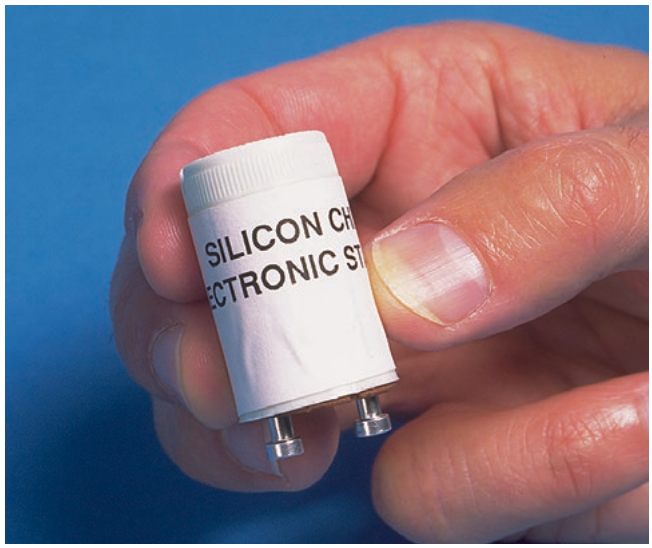
Fig.6: this is the full-size etching pattern for the PC board. Check your board for etching defects by comparing it with this pattern before installing any parts.

Construction

The electronic starter is constructed on a PC board coded 10308961 and measuring 17 x 28mm. This is designed to be a snug fit inside a standard fluorescent starter container. Even so we had to mount components on both sides of the board and in some cases

RESISTOR COLOUR CODES

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	1MΩ	brown black green brown	brown black black yellow brown
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	62kΩ	blue red orange brown	blue red black red brown



The electronic fluorescent starter is mounted inside a dud fluorescent lamp starter case. It will rapidly start slimline (25mm) and conventional (38mm) fluorescent tubes without flashing.

they lie on top of each other, as you will see from the diagram of Fig.5 and the photos.

To put this PC board together you will need either a very keen pair of eyes or better still, a pair of close-up specs or a mag-lamp. IC1 is a surface mount IC so you will need a fine-tipped soldering iron since the IC's legs are spaced only 1.27mm (.050") apart.

Note that since IC1 is a surface-mount type, it is mounted on the copper side of the board. Other components on the copper side are the four diodes, C1 and the 100kΩ and 62kΩ resistors.

Check that the PC board is correct by comparing it with the published pattern. Correct any shorted or broken tracks at this stage. Before soldering anything to the board we suggest that you pre-tin the copper tracks for the IC pins. Then place the IC in position making sure it is oriented correctly. How do you do that?

We did say you will need very good vision. Notice that one end of the IC is chamfered along one side; pin 1 is at the top, if you hold the IC with the chamfered edge at left. This can be seen in Fig.5.

Once you have the tracks for IC1 tinned and it is in position, solder each pin quickly with just enough heat to melt the solder on the PC board. Then check each solder connection is good by measuring the resistance between each pin and the PC track.

On the component side of the PC board side insert and solder in the 1MΩ resistor and the 3.3µF capacitor, taking care with polarity. The capacitor should lie over the 1MΩ resistor. Keep a few mm of lead length between the PC board and capacitor so that it lies more or less parallel with the board. Cut the leads short on the copper side after soldering.

Now install the remaining parts on the copper side. Make sure that the diodes are oriented as shown and cut the leads flush with the PC board side. Now place the .0056µF capacitor over the diodes and bend its leads so that the capacitor body can lie parallel with the board. Solder this in place.

Next, mount the Mosfet on the component side, with its leads bent at right angles so that it lies parallel to and close to the board. It is oriented so that the metal tab faces away from the top of the board. Solder and trim its leads. Lastly, fit a 12mm length of 12mm diameter heatshrink tubing over the Mosfet to completely insulate it.

Starter container

You will need to disassemble a starter for its case and lid with terminals. Use a small screwdriver to carefully prise the Bakelite lid from the cylindrical container. You will need to gradually work around the whole circumference of the container with the screwdriver until the baseplate can be removed.

Withdraw the lid and components and cut the wires close to the capacitor body. These leads are then attached to the PC board of your new electronic starter. Cut the starter tube wires close to the baseplate lug. The capacitor leads can now be inserted into the PC board from the PC board side and soldered in place.

Next, carefully inspect the PC board assembly for any solder dags or splashes or pigtails which are too long. This aspect is most important when you consider the peak voltages which can occur between the leads to the Mosfet and diodes. None of your soldering should diminish the gaps between conductors of the bare board.

When you are satisfied that all aspects of the soldering and assembly are correct, insert the PC board and starter lid assembly into the container and clip in place. Note that the components may need to be pressed closer to the PC board if the fit is too tight.

Finally, test your new electronic starter in a fluorescent light fitting. The tube should initially glow orange at the filaments, then glow white at the tube ends and then light up fully, usually after the first attempt. **SC**

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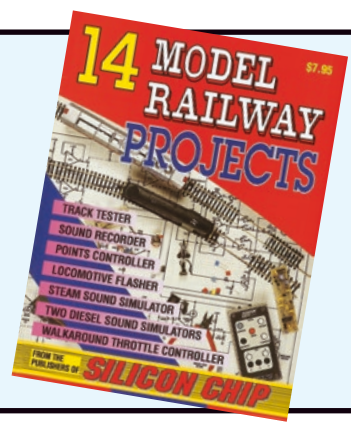

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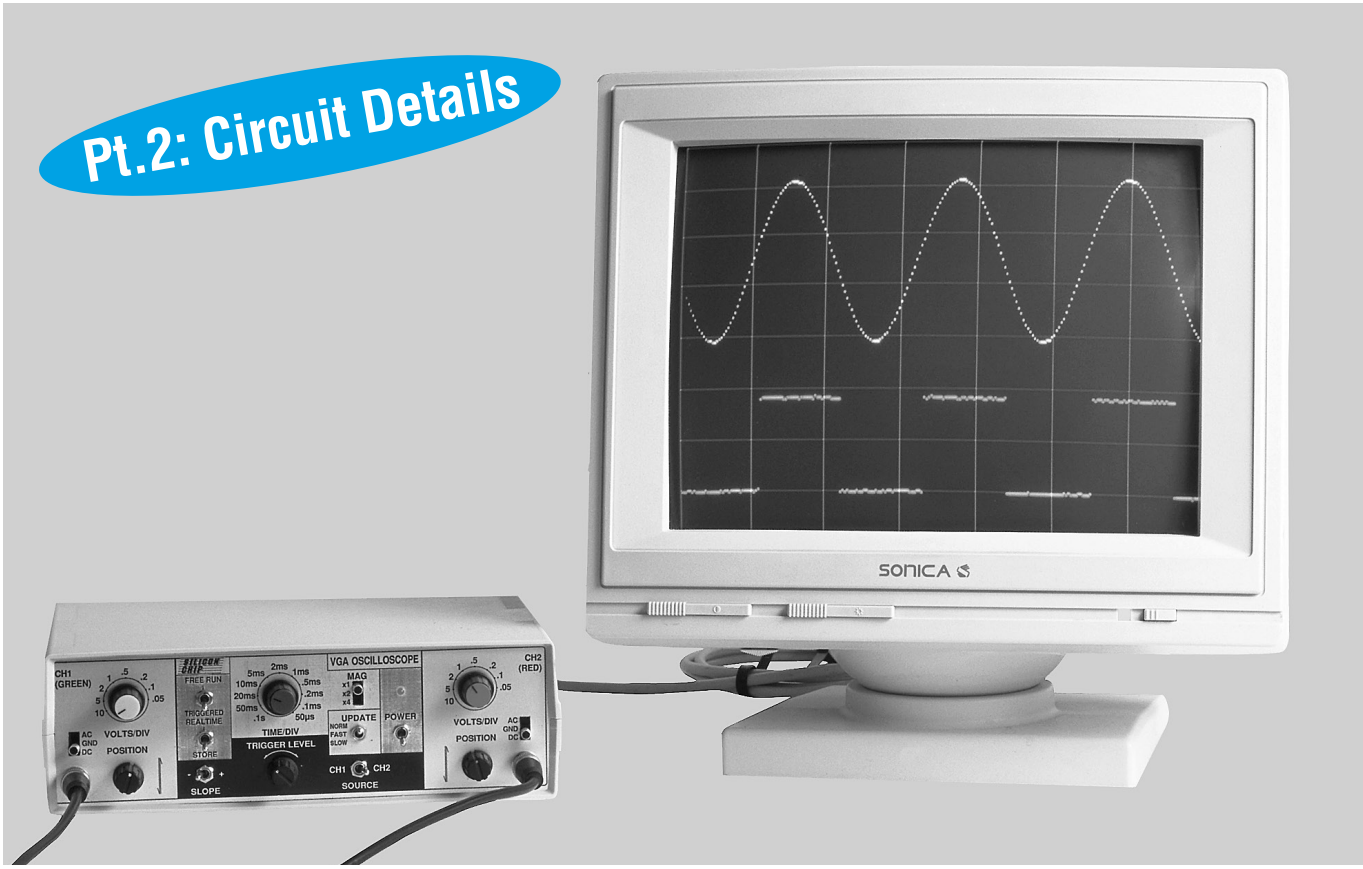


Build a VGA digital oscilloscope

One of the real attractions of this digital scope, based on a VGA monitor, is that you don't have to peer at the display – it is large, bright and the different coloured traces and graticule make it easy to interpret what's happening. In this article we discuss the circuit details.

By JOHN CLARKE

To fully understand the discussion, it will be a help if you can refer to the block diagram presented on page 28 of last month's issue.

The circuit for the VGA Oscilloscope has been split into two sections. The main section is Fig.1, on pages 66 and 67, comprises most of the circuit while the timebase circuit, Fig.3, is shown on page 69.

28 ICs are used in the entire circuit. However, as we shall see, some of the circuit is repetitive (for the CH1 and CH2 inputs) and much of it involves timers and counters.

Looking at the top righthand corner of the two-page circuit, S1 is the AC/DC coupling switch for the Channel 1 input. S1 also has a GND setting to allow the trace to be positioned on the graticule as a ground (zero) reference point.

Following S1, the input signal passes via the attenuator switch S2. This is essentially a string of resistors, with each one bypassed by a capacitor to improve high frequency response. Trimmer capacitor VC1 allows adjustment of the frequency compensation.

After the attenuator, the signal is applied to the gate of JFET Q1 which acts as a high impedance buffer. Its gate is protected from excessive signal excursion by two back-to-back LEDs. These begin to conduct for signals in

PARTS LIST

1 plastic case, 262 x 189 x 84mm, with metal panel
1 front panel label, 252 x 76mm
1 PC board, code 04307961, 252 x 75mm
1 PC board, code 04307962, 213 x 142mm
1 PC board, code 04307963, 252 x 75mm
2 PC boards, code 04307964, 20 x 32mm
3 2P3W slider switches (S1,S3,S11)
3 1-pole 12-way rotary switches (S2,S4,S5)
5 SPDT toggle switches (S6,S7,S8,S9,S12)
1 SPDT centre-off switch (S10)
2 10kΩ horizontal mount trimpots (VR1,VR3)
1 5kΩ horizontal trimpot (VR6)
2 500Ω linear pots (VR2,VR3)
1 5kΩ linear pot (VR5)
2 2-47pF miniature trim capacitors (VC1,VC2)
1 9-68pF miniature trim capacitor (VC3)
1 4MHz parallel resonant crystal (X1)
1 15-pin VGA line socket and lead
1 cable clamp
1 5mm rubber grommet
1 DC panel socket
2 BNC panel sockets
5 3mm LEDs (LEDs 1-5)
3 15mm OD black knobs
3 18mm OD knobs (1 green, 1 blue, 1 red)
92 PC stakes
2 8-way pin headers
1 1.8m length of 0.8mm tinned copper wire
1 150mm length of shielded cable
1 800mm length of 4-way rainbow cable
1 400mm length of red hookup wire
1 400mm length of green hookup wire
1 400mm length of blue hookup wire
1 400mm length of yellow hookup wire
1 400mm length of black hookup wire
3 3mm diameter x 6mm machine screws and nuts

Semiconductors
4 CA3140 op amps (IC1,IC2, IC7,IC8)
2 ADC0820CCN 8-bit A-D converters (IC3,IC9)
2 MCM6206DJ20 20ns 8-bit RAMs (IC4,IC10)
4 74HC85 4-bit magnitude comparators (IC5,IC6,IC11, IC12)
4 7555,TLC555CN CMOS timers (IC13,IC20,IC22,IC28)
4 74HC74 dual D-flipflops (IC14,IC19,IC26,IC27)
1 74HC86 quad EXOR gate (IC15)
1 74HC4053 analog CMOS switch (IC16)
2 74HC193 4-bit presettable counters (IC17,IC18)
1 LM319 dual comparator (IC21)
2 74HC00 quad NAND gates (IC23,IC29)
2 74HC4040 binary counters (IC24,IC25)
1 7812 12V regulator (REG1)
1 7805 5V regulator (REG2)
2 2N5484 JFETs (Q1,Q2)
3 BC338 NPN transistors (Q3,Q6,Q9)
2 BC548 NPN transistors (Q4,Q7)
2 BF199 NPN RF transistors (Q5,Q8)
21 1N914 signal diodes (D1-D16,D21-D25)
4 1N4004 diodes (D17-D20)
5 3mm red LEDs (LED1-5)

Capacitors
1 1000µF 16VW PC electrolytic
1 33µF 16VW PC electrolytic
15 10µF 16VW PC electrolytic
1 6.8µF 16VW PC electrolytic
1 1µF 16VW PC electrolytic
2 0.22µF MKT polyester
14 0.1µF MKT polyester
1 .047µF MKT polyester
4 .0039µF MKT polyester
2 .0015µF MKT polyester
5 .001µF MKT polyester
2 680pF MKT polyester or ceramic
1 560pF MKT polyester or ceramic
1 470pF MKT polyester or polystyrene
2 390pF ceramic
2 150pF ceramic
2 82pF ceramic
3 47pF ceramic
2 22pF ceramic
3 3-60pF trimmer capacitors (VC1-VC3)

Resistors (0.25W, 1%)

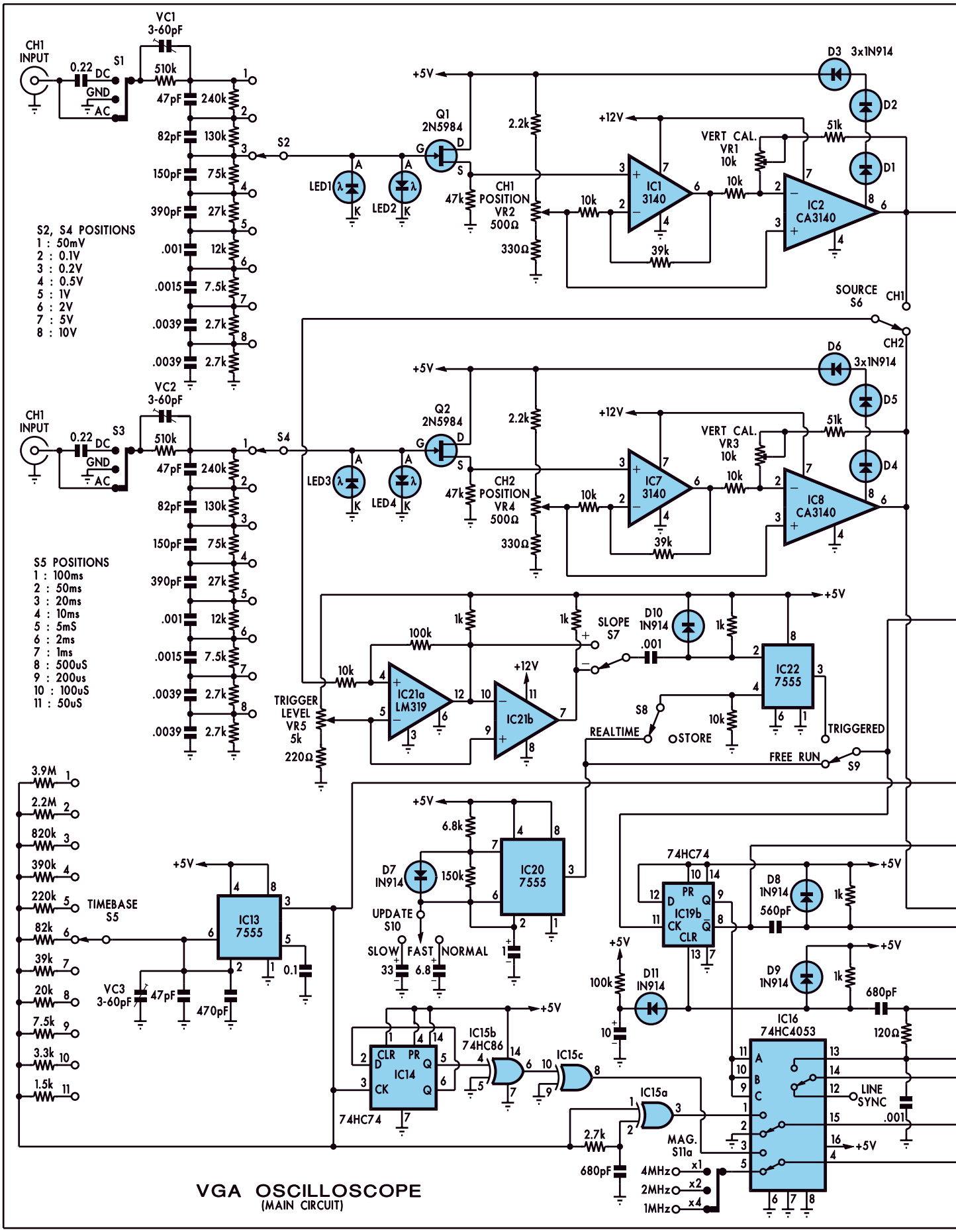
1 10MΩ	1 20kΩ
1 3.9MΩ	2 12kΩ
1 2.2MΩ	6 10kΩ
1 820kΩ	3 7.5kΩ
2 510kΩ	1 6.8kΩ
1 390kΩ	1 3.9kΩ
2 240kΩ	1 3.3kΩ
1 220kΩ	5 2.7kΩ
1 150kΩ	11 2.2kΩ
2 130kΩ	2 1.8kΩ
3 100kΩ	1 1.5kΩ
1 82kΩ	7 1kΩ
2 75kΩ	2 330Ω
2 51kΩ	1 220Ω
2 47kΩ	1 120Ω
3 39kΩ	3 75Ω
2 27kΩ	

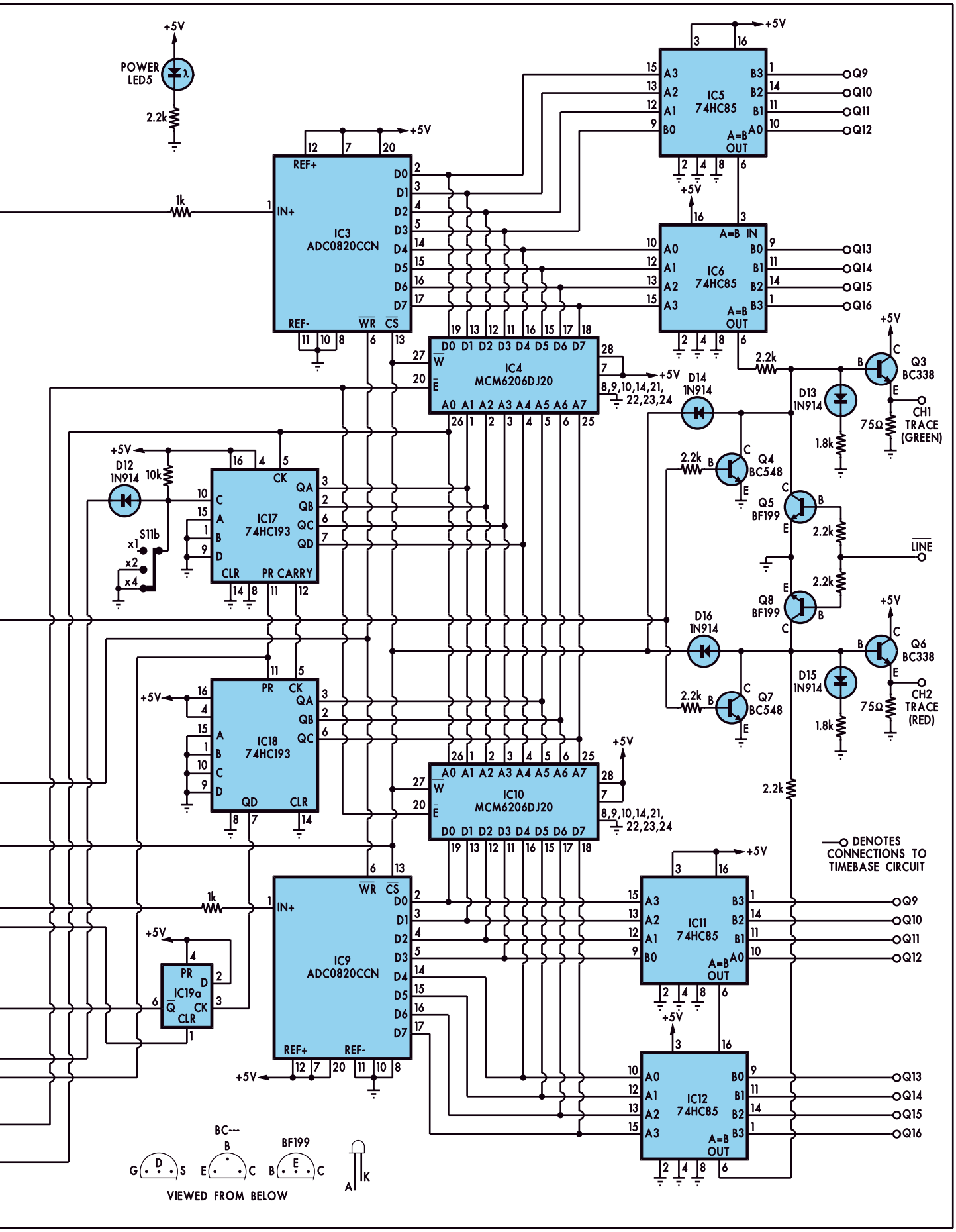
Miscellaneous
Solder, four self-tapping screws, cable ties.

excess of ±1.8V peak and are there mainly to cater for the situation where the input attenuator is set too low for the size of the signal. Normally, if the attenuator is correctly set, the signal at the gate of Q1 will not exceed about ±200mV peak.

IC1 and IC2 invert and amplify the signal by about 25 times to produce sufficient level for the following A-D converter which requires 5V for full conversion. VR2 controls the DC output offset of IC1 and IC2 and thereby has the effect of shifting the signal

Fig.1 (following page): the main circuit section for the VGA Oscilloscope. This comprises the input circuitry, A-D converters (IC3 & IC9), memory storage devices (IC4 & IC10) and the oscilloscope timebase circuitry (IC13-15, IC17 & IC18).


VGA OSCILLOSCOPE
(MAIN CIRCUIT)
CH1 INPUT
VC1 3-60pF
S1
S2
S2, S4 POSITIONS
1 : 50mV
2 : 0.1V
3 : 0.2V
4 : 0.5V
5 : 1V
6 : 2V
7 : 5V
8 : 10V
Q1 2N5984
LED1
LED2
CH1 POSITION VR2 500Ω
IC1 3140
IC2 CA3140
VERT CAL. VR1 10k
D1
D2
D3 3x1N914
SOURCE S6
CH1
CH2
VC2 3-60pF
S3
S4
Q2 2N5984
LED3
LED4
CH2 POSITION VR4 500Ω
IC7 3140
IC8 CA3140
VERT CAL. VR3 10k
D4
D5
D6 3x1N914
S5 POSITIONS
1 : 100ms
2 : 50ms
3 : 20ms
4 : 10ms
5 : 5mS
6 : 2ms
7 : 1ms
8 : 500uS
9 : 200us
10 : 100uS
11 : 50uS
TRIGGER LEVEL VR5 5k
IC21a LM319
IC21b
SLOPE S7
D10 1N914
IC22 7555
S8
REALTIME
STORE
TRIGGERED
FREE RUN
S9
TIMEBASE S5
IC13 7555
IC20 7555
D7 IN914
UPDATE S10
SLOW
FAST
NORMAL
74HC74
IC14
IC15b 74HC86
IC15c
IC15a
IC19b
D8 1N914
D9 1N914
D11 1N914
IC16 74HC4053
LINE SYNC
MAG. S11a
4MHz
2MHz
1MHz
x1
x2
x4


+5V
POWER LED5
2.2k
1k
IC3 ADC0820CCN
REF+
IN+
REF-
WR CS
D0 D1 D2 D3 D4 D5 D6 D7
IC4 MCM6206DJ20
A0 A1 A2 A3 A4 A5 A6 A7
8,9,10,14,21, 22,23,24
IC5 74HC85
IC6 74HC85
A=B IN
A=B OUT
Q9
Q10
Q11
Q12
Q13
Q14
Q15
Q16
D12 1N914
10k
IC17 74HC193
CK
QA
QB
QC
QD
CLR
PR CARRY
S11b
x1
x2
x4
D13 1N914
D14 1N914
D15 1N914
D16 1N914
Q3 BC338
Q4 BC548
Q5 BF199
Q6 BC338
Q7 BC548
Q8 BF199
2.2k
1.8k
75Ω
CH1 TRACE (GREEN)
CH2 TRACE (RED)
LINE
IC18 74HC193
PR
QD
IC10 MCM6206DJ20
IC9 ADC0820CCN
IC19a
IC11 74HC85
IC12 74HC85
DENOTES CONNECTIONS TO TIMEBASE CIRCUIT
BC---
BF199
VIEWED FROM BELOW

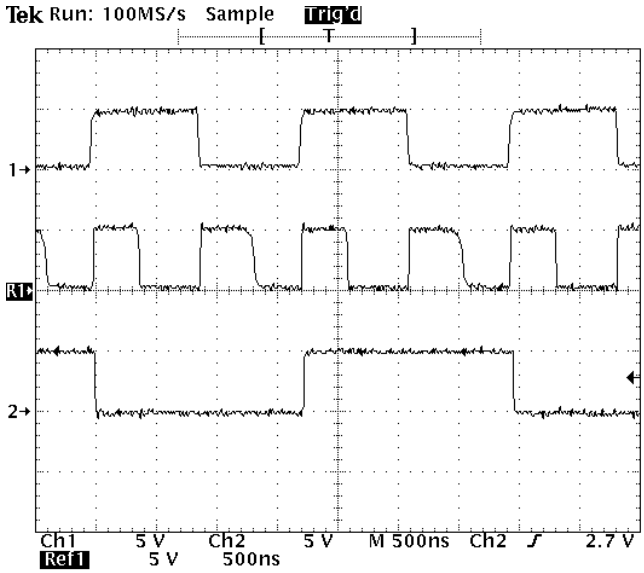


Fig.2: these oscilloscope waveforms show the timing for the record sequence. The top trace is the read/write input of the A-D converters, while the middle trace is the enable input for the memory. The lower trace is the clock input to counter IC17.

trace up or down the VGA screen. VR1, in the feedback loop for IC2, changes the gain for the vertical calibration function.

Note that any change in the setting of VR2 will affect the overall gain of IC1 and IC2 since this is part of the gain setting resistance.

However, the range over which the potentiometer is adjusted to set the waveform fully up or fully down on the screen is only a small percentage change compared to the overall resistance value. As a result, the gain change in not perceivable on the screen.

IC1 and IC2 are powered from 12V in order to ensure an output swing capability of more than 5V, while diodes D1-D3 clamp IC2's output to prevent overload in the following A-D converter.

IC3 is an 8-bit high speed A-D converter with an inbuilt sample and hold feature. It has a 4-bit flash converter which uses 32 comparators to speed up conversion and can convert an analog signal to an 8-bit digital code in a maximum of 1.5µs.

AD conversion is started by a low on the WR-bar input at pin 6 of IC3. This must be low for at least 600ns before going high and must remain high for a minimum of 800ns before the data is valid.

The data output lines are connected to the RAM chip IC4. This is a 20ns access time high speed memory containing 32K bytes. We have only used 256 bytes and although this may seem wasteful, its selection was based on the high speed and cost. Paradoxically, larger memory can be less expensive than the less popular smaller RAM chips.

High speed RAM is paramount for this application. Remember that when the memory is called to cycle through each location when displaying the stored waveform on the screen, the allotted time per memory location is only 125ns (4MHz rate or 250ns period and 125ns per half cycle).

This means that there are 20ns devoted to accessing the correct data and 105ns devoted to comparing this value with the line counter. Any standard 120ns memory would be lost trying to keep up this pace.

Channel 2 signals

The signal process for channel 2 is identical to that described above, the path being via attenuator switch S4, buffer Q2 and amplifiers IC7 and IC8. A-D conversion is in IC9 and the data is stored in RAM chip IC10.

IC17 and IC18, which are synchronous 4-bit preloadable counters, drive the address lines of IC4 & IC10. The clock input at pin 5 of IC17 (which is also the A0 input for IC4 and IC10) is from IC16 at pin 4.

When the oscilloscope is in display mode the clock signal comes from the MAGnification selection at S11a via pin 5 of IC16 and is fed through to pin 4. When in the record mode, the clock is from IC15c at pin 3 of IC16. This indirectly obtains a clock signal from the timebase oscillator, IC13.

Triggering

The outputs of IC2 and IC8 connect to switch S6 and this selects the source of triggering from channel 1 or channel 2. Comparators IC21a and IC21b take the signal from S6 to generate the trigger signal.

IC21a generates trigger signals for positive-going signals while IC21b acts as an inverter to generate trigger signals for negative-going inputs. The trigger threshold (level) is set by VR5. Positive or negative triggering is selected by switch S7.

The comparator output selected by S7 triggers IC22 which is a 7555 timer set up as a one shot. When triggered, its output at pin 3 goes high and remains high until reset by the update oscillator IC20. This occurs when S8 is in the realtime position but IC22 remains set if left in the store position.

IC20 is another 7555 timer which operates as a free running oscillator. It charges the selected capacitor at pin 2 and 6 via a 6.8kΩ resistor and diode D7 and discharges it via the 150kΩ resistor.

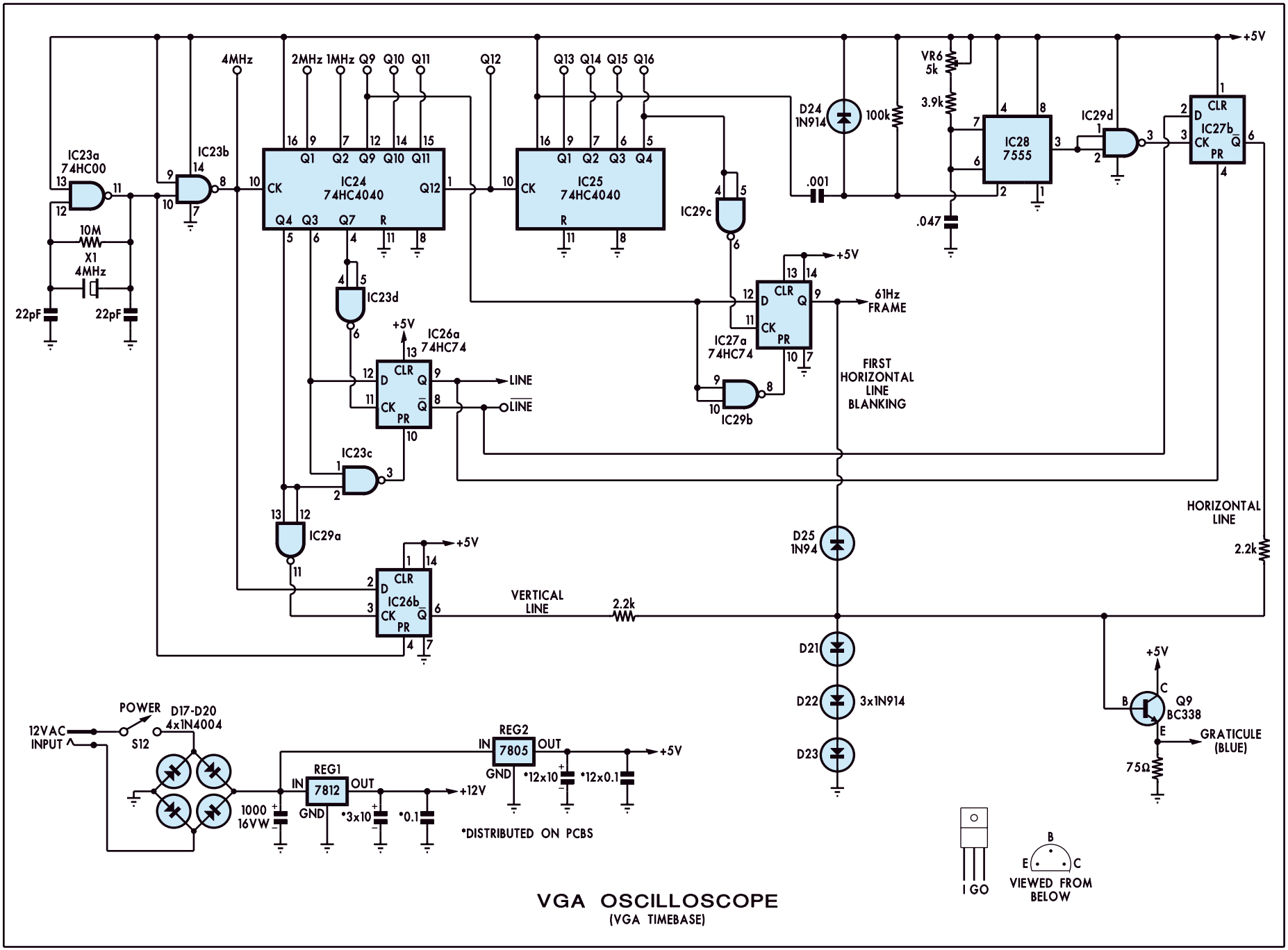
With this setup, its pin 3 output is high for a short time (to reset IC22) and low for a relatively long time to allow triggering from IC21.

Flipflop IC19b is triggered either by IC22 or IC20, depending on the setting of switch S9. In the free run position of S9, the display is updated at a regular interval set by the frequency of IC20. This means that the display will not be locked (ie, it will be moving) since a different part of the waveform will be stored at each trigger point.

The triggered selection for S9 provides a static display since the waveform is stored at the same point in the waveform each time and only when the pin 3 output of IC20 is high.

IC19b is reset when power is first applied, due to the 10µF capacitor at the cathode of D11 being discharged. This pulls the CLR input (pin 13) low to reset the Q output low and the Q-bar output high. When IC19b is triggered,

Fig.3 (right): the VGA timebase circuit. NAND gate IC23a and X1 form a master crystal oscillator, while binary counters IC24 & IC25 provide the 8-bit data signals for IC5, IC6, IC11 & IC12 (on Fig.1).


4MHz
2MHz 1MHz Q9 Q10 Q11
Q12
Q13 Q14 Q15 Q16
+5V
IC23a 74HC00
IC23b
IC24 74HC4040
IC25 74HC4040
IC28 7555
IC29d
IC27b
10M
X1 4MHz
22pF
22pF
IC23d
IC29c
D24 1N914
100k
.001
VR6 5k
3.9k
.047
61Hz FRAME
IC27a 74HC74
FIRST HORIZONTAL LINE BLANKING
IC29b
IC26a 74HC74
LINE
LINE
IC23c
IC29a
IC26b
VERTICAL LINE
2.2k
HORIZONTAL LINE
2.2k
D25 1N94
D21
D22 3x1N914
D23
Q9 BC338
GRATICULE (BLUE)
75Ω
POWER
S12
12VAC INPUT
D17-D20 4x1N4004
1000 16VW
REG1 7812
*3x10
*0.1
+12V
REG2 7805
*12x10
*12x0.1
+5V
*DISTRIBUTED ON PCBS
I GO
VIEWED FROM BELOW
VGA OSCILLOSCOPE
(VGA TIMEBASE)

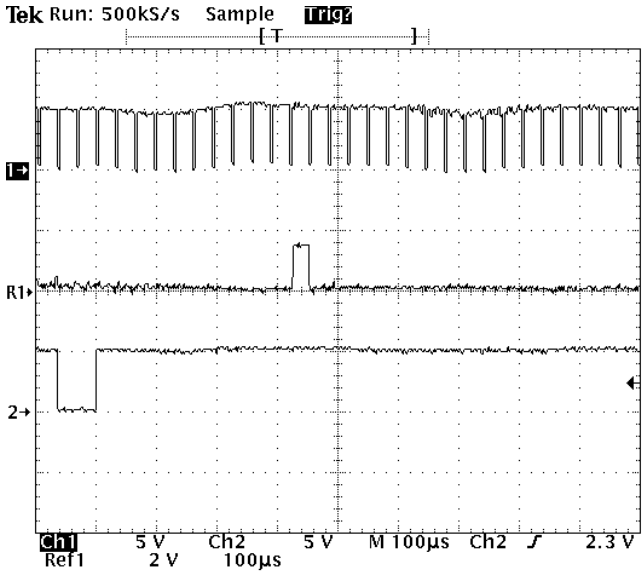


Fig.4: these oscilloscope waveforms show the line sync pulses (top) and the frame sync pulses (bottom). The centre trace is actually a horizontal line for the graticule.

the Q output at pin 9 goes high and operates the three switches inside IC16 via the A, B and C inputs. This switches pin 4 to pin 3, pin 15 to pin 1 and pin 14 to pin 13.

At the same time, the low output at pin 8 of IC19b (Q-bar) selects the ADC chips IC3 and IC9 (via their the CS inputs) and places IC4 and IC10 (RAM) in the write mode.

The low Q-bar output from pin 8 of IC19b also clears IC19a, via the 560pF capacitor connected to pin 1. This causes the Q-bar output of IC19a to go high.

Before this happens, the previously low Q-bar output of IC19a presets IC17 and IC18, via IC16. Diode D12 holds the C preset input (pin 10) of IC17 low and so both counters are preset to 0000 0000. An RC delay from the Q-bar output of IC19a to pin 13 of IC16 is used to extend the preset time for IC17 and IC18.

The above sequence sets the circuit in the record mode. Timebase oscillator IC13 now controls the read/write inputs of A-D converters IC3 and IC9.

Fig.2 shows a screen printout of oscilloscope waveforms of the timing for the record sequence. The top trace is the read/write input of the A-D converters.

When low, the A-D converter samples the data and flash converts the four most significant digits. 800ns after the rising edge of the read/write input, data from the A-D converter is valid.

The middle trace of the oscilloscope waveform is the enable input for the memory. It is derived from the timebase and passes through EXOR gate IC15a (IC15 is near the lower righthand corner of the circuit, Fig.1).

IC15a has its pin 1 input directly connected to the timebase, while pin 2 is connected via an RC delay. Whenever the input to IC15a changes, pin 3 goes high for the delay period to disable the memory. This prevents any false data from the A-D converter being applied to the data inputs of the memory.

The lower trace on Fig.2 is the clock input to counter IC17 which is a divide-by-two timebase signal. The timebase clocks IC14, which is connected as a toggle flipflop. Its output is passed through two EXOR gates, IC15b & IC15c, wired as non-inverters to introduce a small amount of delay between the positive edge of the timebase and the change in the clock signal for IC17.

This ensures that the memory is disabled via IC15a (middle trace) before the address is changed.

When counters IC17 & IC18 have reached a count of 256, the Q_D output at pin 7 of IC18 goes high and clocks D-flipflop, IC19a. This produces a low at the Q-bar (pin 6) output of IC19a and this presets IC17 & IC18.

A low pulse to the CLR input of IC19b via the 680pF capacitor sets the Q output of IC19b low and Q-bar high. The high Q-bar output deselects A-D converters IC3 and IC9 and switches the IC4 and IC10 memories to read mode via the Write-bar inputs at pin 27.

The low Q output switches IC16 so that the clock input of IC17 and address line 0 of IC4 are controlled by the 4MHz to 1MHz inputs at pin 5. These inputs come from the timebase circuit (see Fig.3). Also the memories are permanently enabled via the now low E-bar inputs caused by pin 15 of IC16 connecting to the low pin 2. Counters IC17 and IC18 are now preset by the line sync signal now present at pin 14.

In addition, the low Q-bar output of IC19b clears IC19a via the 560pF capacitor connected to pin 1. Its Q-bar is high and so diode D12 connecting to the C input of IC17 is reverse biased. This input is pulled high via the 10kΩ resistor when S11b is in position 1. Preloading of IC17 now sets it to an initial count of 8.

This may appear unusual, however it is used to move the oscilloscope trace along the screen so that the trigger point is exactly in line with the far left graticule vertical line.

Magnitude comparators

IC5 and IC6 (top righthand corner of Fig.1) are digital magnitude comparators with "less than", "greater than" and "equal-to" outputs. For our application we only use the "equal-to" output, pin 6, which turns on the display when the data from IC4 (channel 1 RAM) is identical to the line count from the VGA timebase circuitry.

Pin 6 drives the base of transistor Q3 via a 2.2kΩ resistor. This is level-clamped using diode D13 and the 1.8kΩ resistor. The emitter follower configuration of Q3 drives the video input (green) of the VGA monitor via a 75Ω resistor. Thus the channel 1 trace is green.

Transistors Q4 and Q5 are for blanking the display when updating the A-D conversion and during the line sync pulse respectively. This prevents the trace from producing an unusual display or overscanning.

Q6, Q7 and Q8 operate in the same manner as above for the channel 2 trace; ie, Q6 drives the red gun of the VGA monitor, while Q7 & Q8 are for blanking. Q6 is driven by pin 6 of IC12. IC11 & IC12 are the digital magnitude comparators for channel 2.

Power

Power for the circuit is derived from a 12VAC plugpack which is rectified

using D17-D20 and filtered with a 1000µF capacitor. REG1 and REG2 provide the +12V and +5V supplies for the circuit.

The 10µF capacitors at the output of each regulator prevent instability. There are also a number of 10µF and 0.1µF decoupling capacitors across the supply rails.

VGA timebase

The VGA timebase circuit is shown in Fig.3. NAND gate IC23a is the master crystal oscillator operating at 4MHz. A 10MΩ resistor between pins 11 and 12 biases the inverter into the linear mode. Crystal X1 oscillates across the inverter pins with the 22pF capacitors providing loading to prevent overtone oscillation.

IC23b inverts the clock signal and both this signal and the pin 11 output from IC23a is applied to the Data (pin 2) and the Preset (pin 4) inputs of flip-flop IC26b. IC26b is a D-flipflop and the inverted level at the Data input is clocked through to the Q-bar output on the positive edge of the CK input at pin 3.

When the preset is low, the Q-bar output is set low.

Graticule generation

IC24 is a binary counter with outputs from Q1-Q12. These are advanced on the negative transition of the clock input at pin 10. Its Q4 output runs at 250kHz and this is inverted with IC29a to clock IC26b.

When Q4 goes low and when the Preset input of IC26b is high, the Q-bar output of IC26b goes high. As soon as the Preset goes low again after 125ns the Q-bar output goes low again. This output produces a vertical graticule line signal 125ns wide and is repeated at a 250kHz rate or every 4µs.

This means that we have 8 vertical graticule lines in the allotted 32µs for each line.

The vertical line signal drives buffer transistor Q9 via a 1kΩ resistor. The three series diodes limit the base drive to 1.8V and the emitter to 1.2V.

The line sync pulses are derived using IC26a which works in the same manner as IC26b.

When the Preset input at pin 10 is low, the Q output at pin 9 goes high when Q7 of IC24 goes low. The result is a 2µs (set by the Q3 output of IC24) low-going pulse at the Q output of IC26a.

This occurs every 32µs as set by the Q7 output of IC24. Note that the use of IC23c to NAND the Q3 and Q4 outputs of IC24 before being applied to the Preset input of IC26a essentially shifts the line sync pulse so that it occurs before the first vertical graticule line.

IC25 is a second binary counter to give us the requisite Q13-Q16 outputs. Note also that Q9-Q16 are the line counter outputs used for comparators IC5 and IC6 and IC11 and IC12.

Similarly, the 4MHz, 2MHz and 1MHz outputs are used to clock the memories when in the playback mode, as selected by switch S11a.

Frame sync pulses

Frame sync pulses are derived in a similar way to the vertical graticule line and line sync pulses. Q16 from IC25 provides a 61Hz signal, while Q9 from IC24 gives a 64µs pulse width.

The oscilloscope waveforms in Fig.4 show the line sync pulses (top trace) and the frame sync pulse (bottom trace).

The centre trace is actually a horizontal line for the graticule. Note that it occupies an entire line height from one line sync pulse to another.

IC28 is triggered by the Q13 output which occurs at eight times the frame frequency. This gives us a possible eight horizontal graticule lines.

Unfortunately, this number does not result in a graticule in the centre of the screen. And a central graticule line is a very desirable oscilloscope feature.

In order to obtain this, timer IC28 is used to delay the occurrence of each line so that one will actually be in the centre.

The .047µF capacitor along with the 3.9kΩ resistor and trimpot VR6 set the delay at about 2048µs.

The horizontal line signal from IC28 is inverted and clocked through IC27b for a horizontal line signal which is locked into the line sync pulse.

The horizontal graticule line is also buffered by Q9 before being applied to the blue gun input of the monitor.

This completes the circuit description. Next month we will present the construction details of the VGA Oscilloscope. SC

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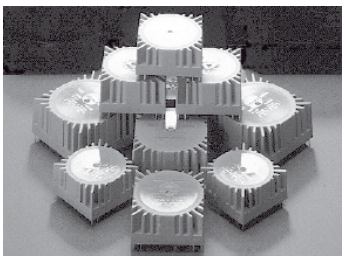

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Rugged Mosfet Audio Amplifier Module

By LEO SIMPSON

Want a big powerful amplifier module based on Mosfets? This one uses eight plastic Mosfets to deliver just over 200 watts into an 8Ω load and a whisker over 350 watts into a 4Ω load – just the ticket for heavy duty amplification.

For many audio enthusiasts, Mosfets rule supreme and Hitachi Mosfets are the best there are. But in the last few years, Exicon, a manufacturer from England, has appeared on the scene with a range of plastic power Mosfets. This new design features these plastic devices which are rated at 20 amps, 200V and 125W. Eight of these devices – ie, four Exicon ECX10P20 p-channel and four ECX10N20 n-channel – are used in this amplifier module.

As the graphs of Fig.1 & Fig.2 demonstrate, the amplifier module will deliver just over 200 watts into an 8Ω load or just over 350 watts into a 4Ω load, at the onset of clipping. The onset of clipping is where the harmonic distortion graph suddenly becomes almost vertical.

While we're talking about performance graphs, we might as well refer to a few more. Fig.3 shows the frequency response which is 0.7dB down at 10Hz and 20kHz. While it is just off the graph, the -3dB point is at 54kHz.

Fig.4 shows the harmonic distortion versus frequency for the power amplifier module when delivering 250 watts into a 4Ω load. Fig.5 shows harmonic distortion versus frequency at 150 watts into an 8Ω load. As these graphs show, the performance is quite respectable.

The amplifier module is also very quiet, which is as it should be for any modern design. We measured a signal-to-noise ratio of 117dB unweighted (22Hz to 22kHz) and 123dB A-weighted with respect to full power into an 8Ω load.

The PC board is designed so that the eight Mosfet power devices are mounted onto a heatsink angle bracket which then mounts on a large finned heatsink as part of the amplifier chassis. Our photos show only the heatsink bracket. **The amplifier must not be operated without a larger heatsink as it will rapidly overheat.**

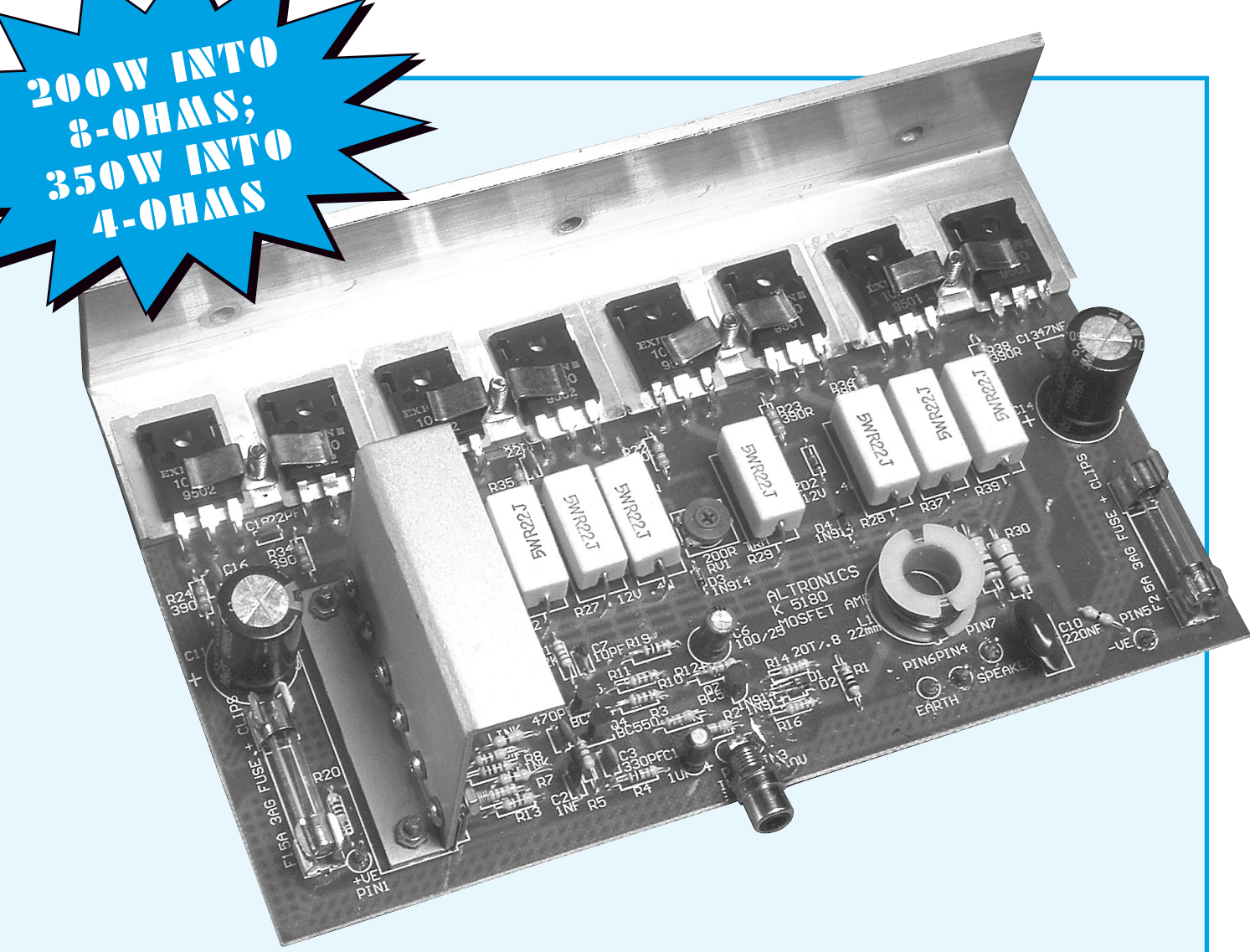
Circuit description

Fig.6 shows the circuit diagram. This amplifier is unlike most direct-coupled circuits in that it has three differential stages to give it high open-loop gain before negative feedback is applied.

Two BC546 NPN transistors, Q4 & Q5, form the differential input stage and their operating current is set by the constant current source, Q7.

The signals at the collectors of Q4 and Q5 are then fed into the voltage gain stage which comprises Q1, Q2, Q3, Q6, Q8, Q9 and associated components. This can best be described as a "double differential pair with

200W INTO 8-OHMS; 350W INTO 4-OHMS



current mirror load". This stage works as follows. PNP transistors Q2 and Q3 form the first differential pair with R8 as the common emitter resistor. The output of Q2, Q3 provide differential drive to NPN transistors Q6 & Q8. The collector load for these two transistors is provided by the current mirror transistors Q1 & Q9.

The current mirror ensures equal current sharing in the associated differential pair and thereby provides high gain and good linearity.

Finally, we come to the power output stage which is the business end of the amplifier; it employs the eight Mosfets mentioned earlier. These are connected as complementary source-followers which means that they behave in a similar way to emitter followers – their voltage gain is a little less than unity but they have oodles of current gain. In effect, the Mosfets act as a buffer stage for the amplifier, transforming the voltage drive from the earlier stages to a low impedance output which can deliver a great deal of power – 350 watts in fact!

The signal at the collectors of Q8 and Q9 (ignore VR1 for the moment) is applied to the gates of the paralleled Mosfets, via the 390Ω resistors. As the signal rises towards the positive rail, the top Mosfets (10N20's) start to conduct, allowing current to flow to the load. Conversely when the signal goes towards the negative rail, the bottom Mosfets (10P20's) conduct, pulling current out of the load.

Performance

Output power	200 watts into 8Ω; 350 watts into 4Ω
Frequency response	-0.7dB down at 10Hz and 20kHz (see Fig.3)
Input sensitivity	1.7V RMS (for 200 watts into 8Ω)
Harmonic distortion	less than .01% (see Figs.1 & 2)
Signal to noise ratio	117dB unweighted (22Hz to 22kHz); 123dB A-weighted with respect to full power into 8Ω
Stability	unconditional

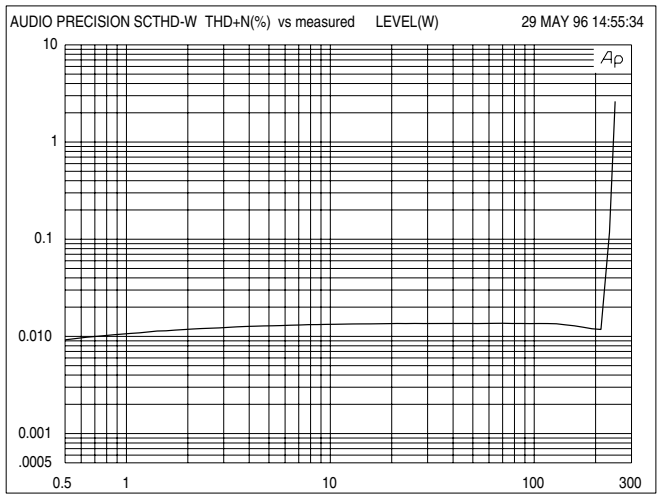


Fig.1: total harmonic distortion versus power into an 8Ω load. Power at the onset of clipping is 212W.

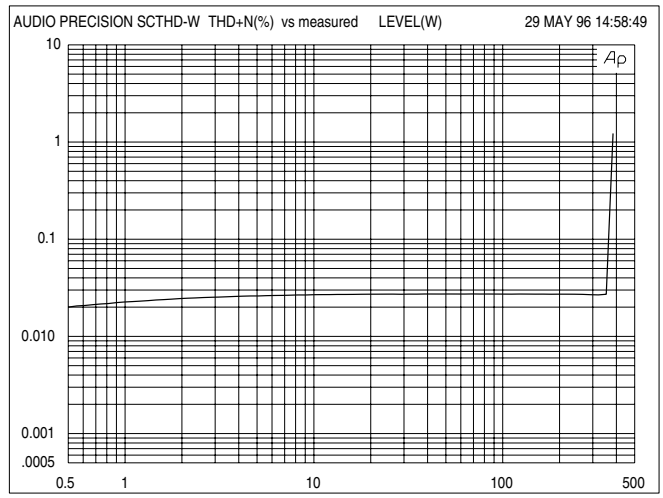


Fig.2: total harmonic distortion versus power into a 4Ω load. Power at the onset of clipping is 353W.

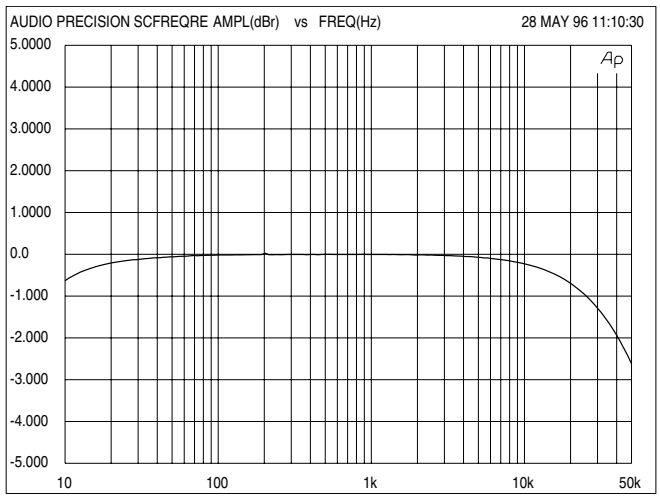


Fig.3: frequency response of the amplifier. While it is just off the graph, the upper -3dB point is at 54kHz.

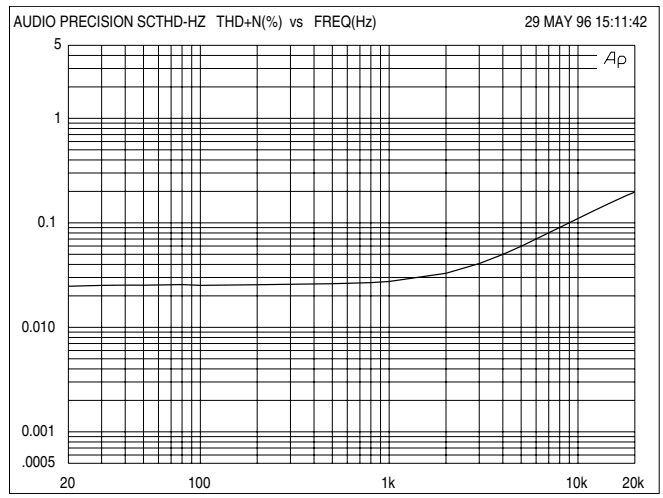


Fig.4: total harmonic distortion versus frequency for the amplifier module when delivering 250W into a 4Ω load.

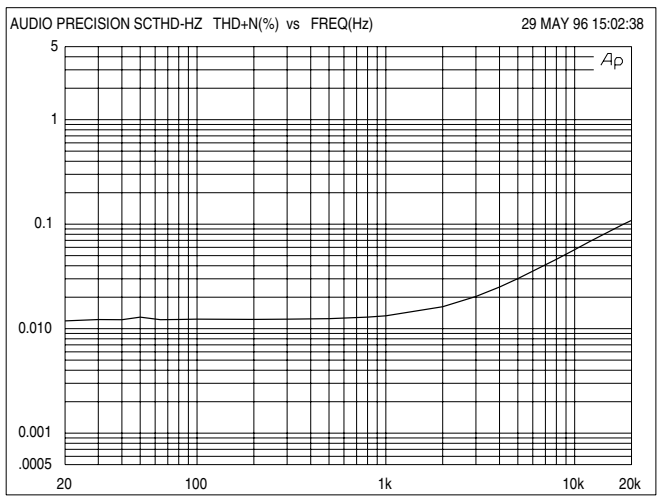


Fig.5: total harmonic distortion versus frequency at 150W into an 8Ω load.

The 390Ω gate resistors are there to act as "stoppers" for the Mosfets. They act in conjunction with the high gate capacitance of the Mosfets to reduce their gain at very high frequencies. This prevents the tendency of Mosfets to "parasitic oscillation" which is typically manifested as bursts of high frequency oscillation (typically at 10MHz or higher) superimposed on the audio signal.

Sometimes parasitic oscillation in Mosfets can be at such a high frequency that it will not be seen on typical 20MHz oscilloscopes; 100MHz or higher bandwidth scopes are necessary to show it.

However, even though it may be invisible on a typical oscilloscope, it is most important to stop it happening because paradoxically, even though it is at such a high frequency, it will cause the harmonic distortion to be much higher than it otherwise would be and the amplifier will sound unpleasant as a result. Anyhow, that's why the stoppers are included.

Capacitors C16-C19 are included to match the input capacitance of the n-channel devices to that of the p-channel types. This improves the gain linearity at high audio frequencies.

The 0.22Ω 5W resistors in series with the source of each Mosfet are there to provide a degree of local negative feed-

back and to help improve the current sharing between devices.

Trimpot VR1 is connected between the collectors of Q9 and Q8 and is there is provide a voltage offset between the gates of the n-channel devices at the top and the p-channel devices below. This voltage offset becomes a forward bias which turns on the Mosfets slightly in the absence of any audio signal. This quiescent (ie, no signal) bias is necessary to operate the Mosfets in the more linear region of their transfer curve and thus reduces crossover distortion.

Zener diodes ZD1 & ZD2 and diodes D3 & D4 protect the gates of the Mosfets from overdrive. The zeners and diodes clamp the drive voltage between gate and source of each Mosfet to a maximum of about +12.7V. Since the Mosfets act as source-followers you might wonder how the gate voltage could go this high.

Normally, the peak current (at full power into a 4Ω load) would be no more than about 3-4A. Since the transconductance of these Mosfets is about 1 Siemen or 1V/A, then the gate-source voltage can be expected to rise to no more than about 4V or so under normal drive. So how could the gate voltage ever rise much above this figure?

The answer is that the gate drive becomes excessive when the load of the amplifier is short-circuited and it is being driven hard. Under these conditions, the gate voltage to the Mosfets could easily rise above 20 volts.

However, the zener diodes do not provide short-circuit protection to the amplifier. That is provided solely by the fuses. The Mosfets are rugged enough to withstand short circuits until the fuses blow.

Negative feedback is applied from the output of the amplifier, via R21, a 22kΩ resistor, to the base of Q5, part of the first differential pair. The AC gain is set by the ratio of the 22kΩ and 1kΩ resistors at the base of Q5 and this gives a value of 23. The resulting input sensitivity of the amplifier is 1.7V RMS for 200 watts into 8Ω and 1.6V RMS for 350 watts into 4Ω.

The low frequency response of the amplifier is set by two time-constants. The first is made up of the 1µF input capacitor C1 and the 47kΩ input bias resistor R3, giving a -3dB point of 3.3Hz. The second time-constant is provided by the 1kΩ feedback resistor

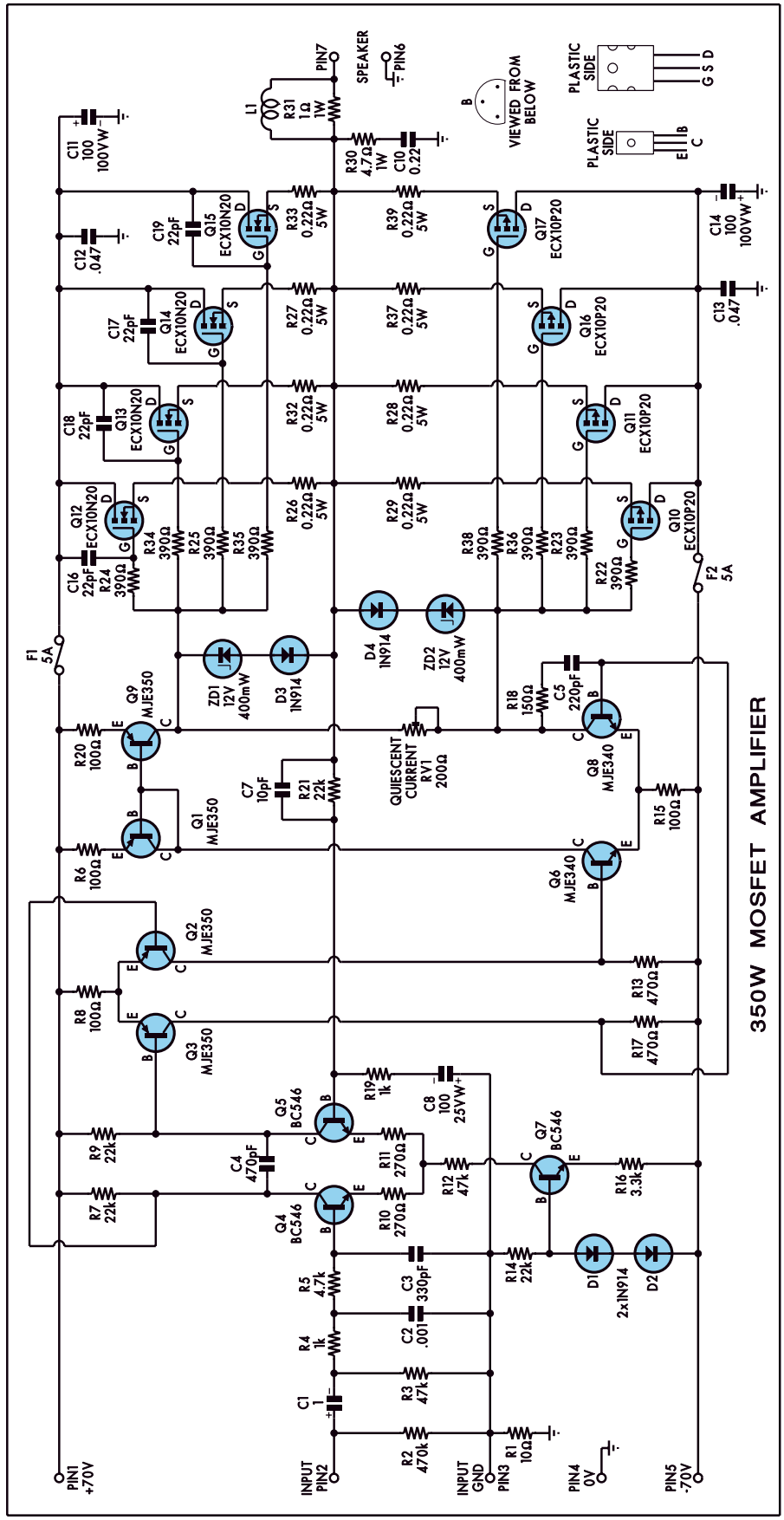


Fig.6: this power amplifier is unlike most direct-coupled circuits in that it has three differential stages to give it high open-loop gain before negative feedback is applied.

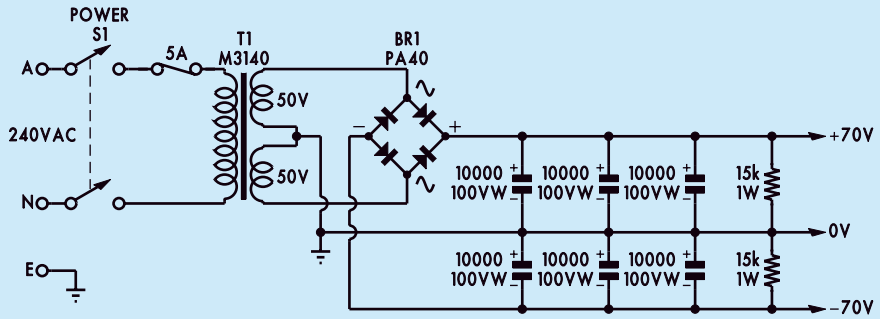


Fig.7: this diagram shows a suggested power supply for the amplifier. The power transformer is rated at 500VA.

R19 and the 100µF capacitor C8, giving a -3dB point of 1.6Hz. Combined, they result in a response which is only -0.7dB at 10Hz.

At the high frequency end, the main determinant of the response is the double time-constant provided by the input network consisting of R4, R5, C2 & C3 which produce a rolloff above 80kHz. Other factors affecting the high frequency response are the 10pF capacitor shunting the feedback resistor R21 and the output coupling network consisting of R30, R31, L1 & C10. The latter network is included to ensure stability of the amplifier under reactive load conditions.

Power supply

And now a few words about the power supply.

Ideally, you need a supply which can deliver over 300 watts if you are using an 8Ω load and almost 600 watts if you are using a 4Ω load. A good compromise is to use a 500VA transformer and six 10,000µF capacitors, as shown in Fig.7.

Note that the DC supply rails are ±70V, a total of 140V between rails. **This is a potentially lethal voltage so be very careful when making measurements around the circuit!**

Construction

As supplied in the kit from Altronics, the PC board has a solder mask and screen printed component overlay, to make assembly straightforward. The component overlay diagram is shown in Fig.8.

Start construction by fitting the PC pins and the resistors, then install the diodes, capacitors and small signal transistors. Watch the orientation of the electrolytic capacitors, diodes and transistors. Don't confuse the 1N914s and 12V zener diodes.

Mount the 5W resistors about 3mm off the PC board, just in case they get hot. Choke L1 is wound with 20.5 turns of 0.8mm enamelled copper wire onto a 14mm plastic former. Once it is wound, scrape the enamel off the wire ends and then tin them with solder before installing the choke on the board.

When installing the fuse clips, take note of their little lugs which should be on the outside ends of the fuse.

Heatsink bracket

The next task is to assemble the MJE340 and MJE350 transistors onto the heatsink bracket. A total of six transistors need to be mounted. If you hold the bracket so that it's facing you, three MJE350s (Q2, Q3, Q1) are mounted on the left, then the two MJE340s (Q6, Q8) and then another MJE350 (Q9). It is most important not to mix them up.

We should also make a note about the brand of MJE340s and 350s. As we have stated in the past, Motorola devices are the best. Other brands will work but they are nowhere near as good, giving rise to less power output and higher distortion.

Fig.9 shows the details of how each MJE340 and MJE350 is mounted to the heatsink bracket. You can use mica washers and heatsink compound for each transistor or use silicone impregnated thermal washers. Do not overtighten the mounting screws.

When all six TO-220 transistors are mounted on the bracket, it can be installed on the PC board and the transistor leads soldered.

An easier method is used to secure the power Mosfets to their heatsink

RESISTOR COLOUR CODES

❑	No.	Value	4-Band Code (5%)	5-Band Code (1%)
❑	1	470kΩ	yellow violet yellow gold	yellow violet black orange brown
❑	2	47kΩ	yellow violet orange gold	yellow violet black red brown
❑	4	22kΩ	red red orange gold	red red black red brown
❑	1	4.7kΩ	yellow violet red gold	yellow violet black brown brown
❑	1	3.3kΩ	orange orange red gold	orange orange black brown brown
❑	2	1kΩ	brown black red gold	brown black black brown brown
❑	2	470Ω	yellow violet brown gold	yellow violet black black brown
❑	8	390Ω	orange white brown gold	orange white black black brown
❑	2	270Ω	red violet brown gold	red violet black black brown
❑	1	150Ω	brown green brown gold	brown green black black brown
❑	4	100Ω	brown black brown gold	brown black black black brown
❑	1	10Ω	brown black black gold	brown black black gold brown
❑	1	4.7Ω	yellow violet gold gold	yellow violet black silver brown
❑	1	1Ω	brown black gold gold	brown black black silver brown

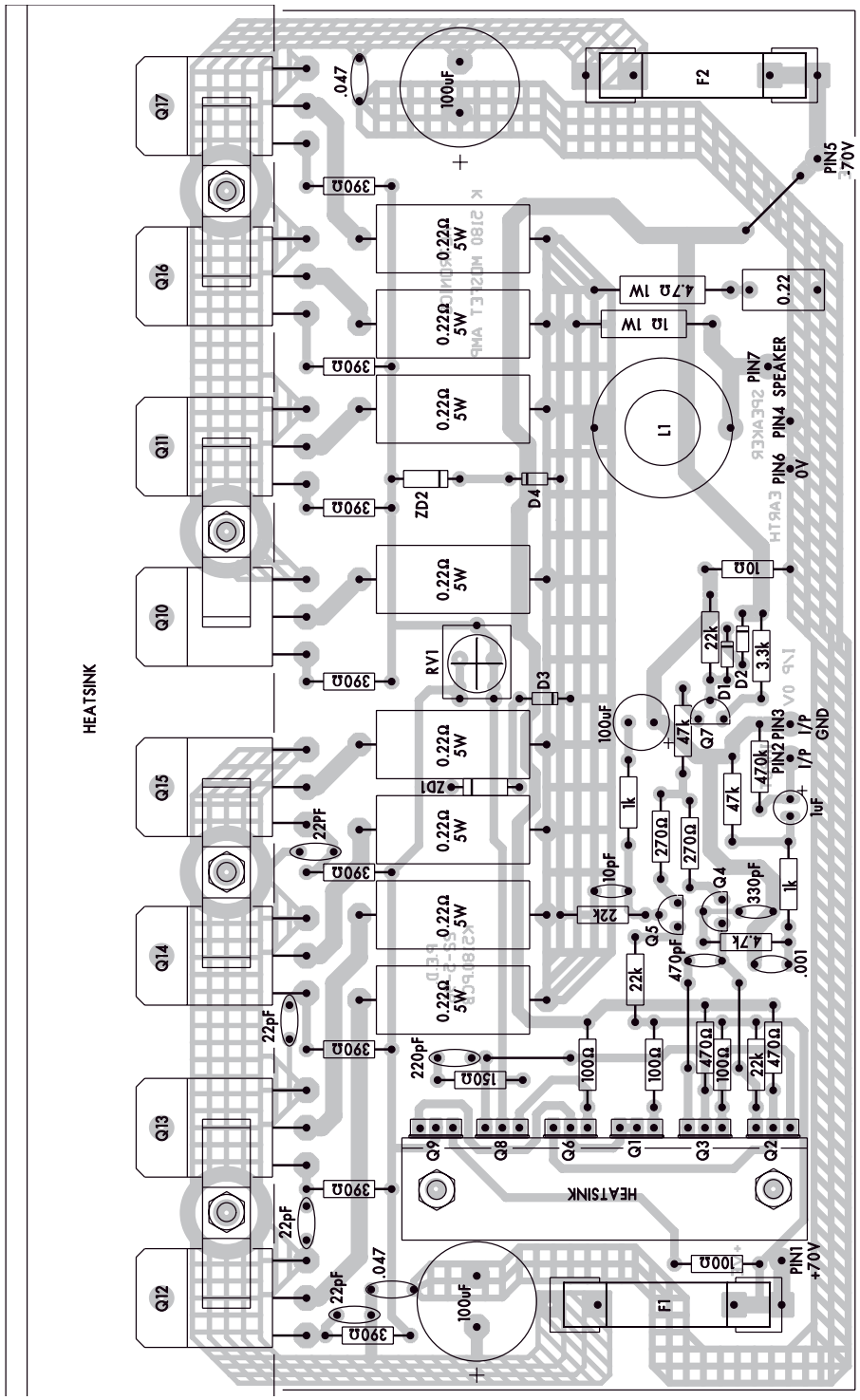


Fig.8: the parts overlay for the PC board. Note that the 5W resistors should be spaced 3mm off the board. Take care to ensure that all polarised parts are correctly oriented.

bracket. Spring clips are used to clamp adjacent transistors. The screw which retains the spring clip also secures the heatsink bracket to the PC board. A cross-section diagram of the mounting is shown in Fig.10.

All eight Mosfets are soldered to the PC board first, making sure that there is about 8mm of lead length above the board. This allows them to be bent over without placing too much strain on the leads. When the eight Mosfets are soldered in place, the heatsink bracket and spring clips can be assembled together. Do not forget to use a mica washer and heatsink compound for each device.

Place a spring clip over two Mosfets

PARTS LIST

1 PC board, code PEDK5180, 205 x 97mm
4 3AG fuse clips
2 5A 3AG fuses
1 large heatsink bracket
1 large single sided heatsink
1 small heatsink bracket
8 TO-3P mica insulating washers
6 TO-220 mica insulating washers
4 transistor mounting clips
7 PC pins
1 plastic bobbin
1 1.2m length of 0.8mm enamelled copper wire
1 200Ω horizontal trimpot (VR1)

Semiconductors

4 ECX10N20 n-channel Mosfets (Q12,Q13,Q14,Q15)
4 ECX10P20 p-channel Mosfets (Q10,Q11,Q16,Q17)
4 MJE350 PNP driver transistors (Q1-Q3,Q9)
2 MJE340 NPN driver transistors (Q6,Q8)
3 BC546 NPN transistors (Q4,Q5,Q7)
4 1N914, 1N4148 signal diodes (D1-D4)
2 12V 400mV zener diodes (ZD1,ZD2)

Capacitors

2 100µF 160VW electrolytic
1 100µF 25VW electrolytic
1 1µF 63VW electrolytic
1 0.22µF metallised polyester
2 .047µF monolithic
1 .001µF greencap
1 470pF disc ceramic
1 330pF disc ceramic
1 220pF disc ceramic
4 22pF disc ceramic
1 10pF disc ceramic

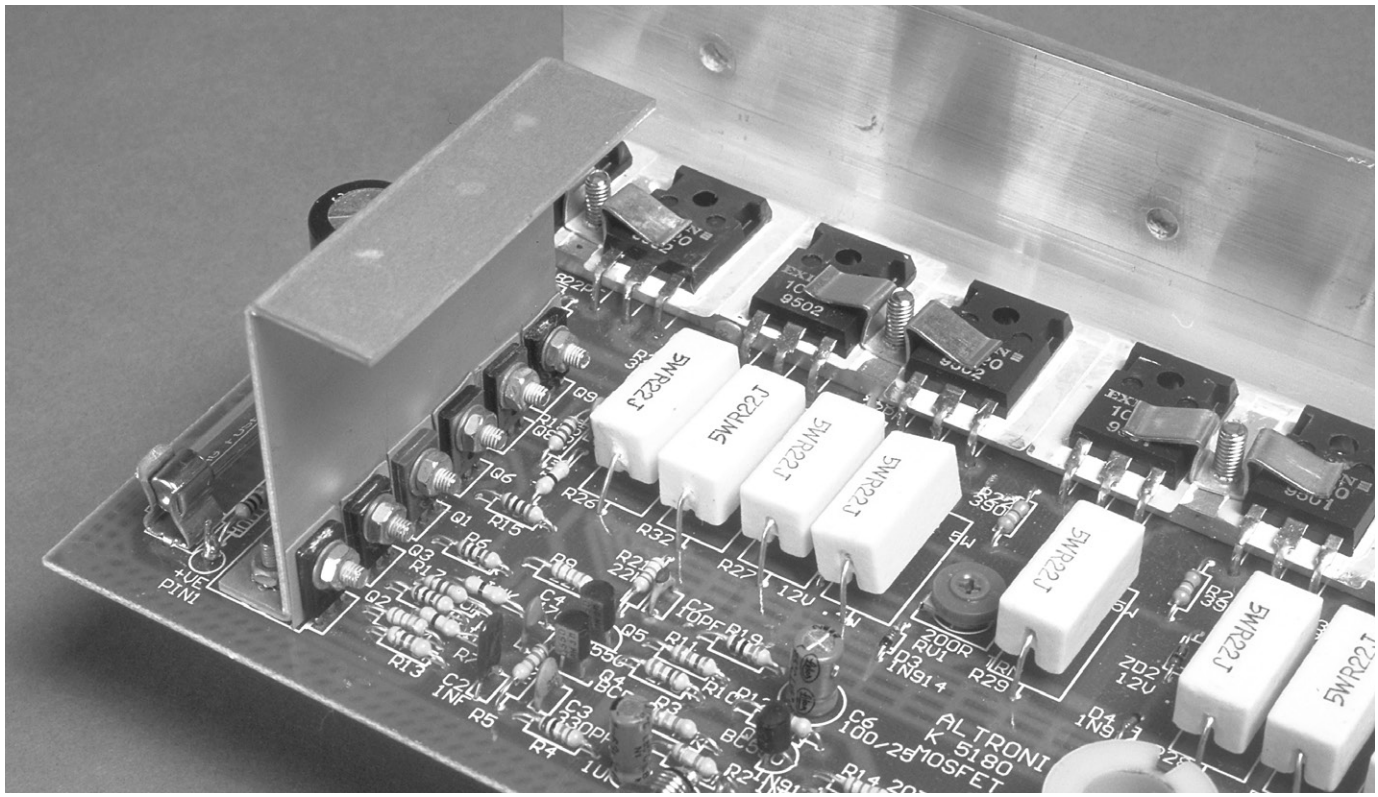
Resistors (0.25W, 5%)

1 470kΩ	8 390Ω
2 47kΩ	2 270Ω
4 22kΩ	1 150Ω
1 4.7kΩ	4 100Ω
1 3.3kΩ	1 10Ω
2 1kΩ	1 4.7Ω 1W
2 470Ω	1 1Ω 1W

8 0.22Ω 5W wirewound
4 zero-ohm links
2 100Ω 5W (for biasing setup)

Miscellaneous

Screws, nuts, washers, solder, heatsink compound.



and then, using a 4mm screw from under the board, secure it to the heatsink bracket. The screw for each clip should be fully tightened; the beauty of these spring clips is that you cannot apply too much force to the Mosfets.

Make sure that all devices are insulated from the heatsink bracket. Check that all six TO-220 devices are insulated from their heatsink bracket as well.

Now check over all your assembly work, making sure that the component installed in each position agrees with that on Fig.8.

Setting up and testing

You will need a power supply (see Fig.7), a multimeter and a small screwdriver to set up the module.

Remove the two fuses and solder a 100Ω 5W wirewound resistor across each fuseholder. Rotate trimpot RV1 fully anticlockwise. This setting will result in the minimum quiescent current through the output stage. Connect the ±70V supply rails and ground to the board. Don't connect a signal or a load at this stage.

Set your multimeter to DC volts and connect it across one of the 100Ω resistors on the fuse clips. Now switch on. No smoke? Good! If all is not well, switch off immediately!

Assuming no smoke, measure the voltage across the 100Ω fuse clip

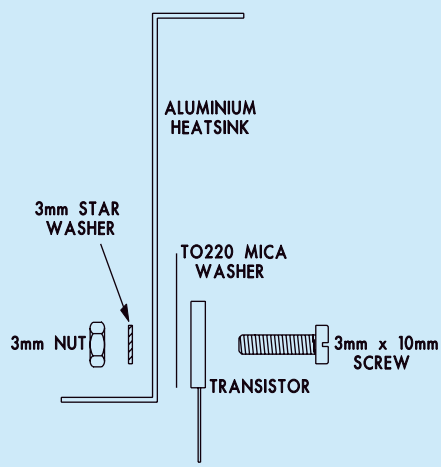


Fig.9: here's how the six TO-220 transistors are mounted on the heatsink bracket. You can use mica washers and heatsink compound for each transistor or silicone impregnated thermal washers.

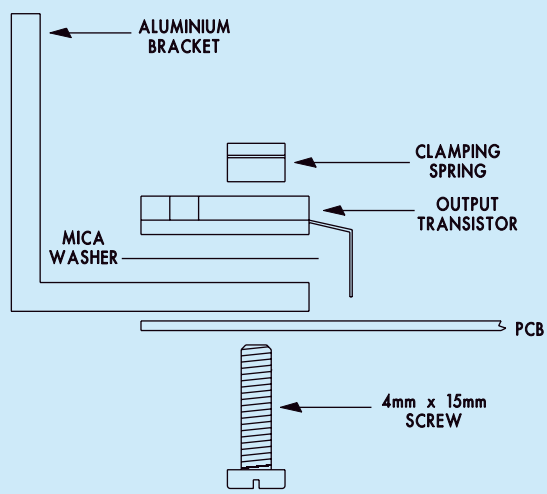


Fig.10: this diagram shows the mounting details for the power Mosfets. Spring clips are used to clamp adjacent transistors.

Kit Availability

The design copyright for this project is owned by Altronics in Perth. They can supply a complete kit for the amplifier module, heatsinks, chassis and power supply components. The amplifier module is priced at $189. (Cat K-5180).

resistor. It should be quite low, about 1V or so. Now rotate trimpot RV1 anticlockwise until the meter reads about 7V. This means that the output state quiescent current is 70 milliamps.

Now measure the voltage across the other 100Ω fuse clip resistor; it should be about the same. Next, measure the voltage across the speaker outputs. The voltage can positive or negative but should be less than 50mV.

Let the amplifier run in this condition for 10 minutes or so, to let the bias stabilise. Re-measure the voltage across the 100Ω resistors and adjust trimpot RV1 if necessary.

The next job is to fit the amplifier with a suitable heatsink and mount it inside a case with a cooling fan and power supply. You can then connect a loudspeaker and signal source and listen to your heart's content.

Troubleshooting

If the 100Ω resistors smoked when power was applied, then check the following:
(1). Bias pot turned wrong way (should be anticlockwise).
(2). Power Mosfets transposed (N types with P types).
(3). Power supply wrongly connected.
(4). Short on underside of PC board.
(5). Output device(s) shorted to heatsink(s).
(6). Shorted capacitor on power supply (check greencaps and electrolytics).

If the current is unstable (ie, jumps all over the place), or the sound us crackly or hissy, then the amplifier is possibly unstable. Check the following:
(1). Wrong values of resistors in the signal section (check them all).
(2). Ceramic capacitors are incorrect value.
(3). Earth or ground connection missing.
(4). Mosfet shorted to heatsink. **SC**

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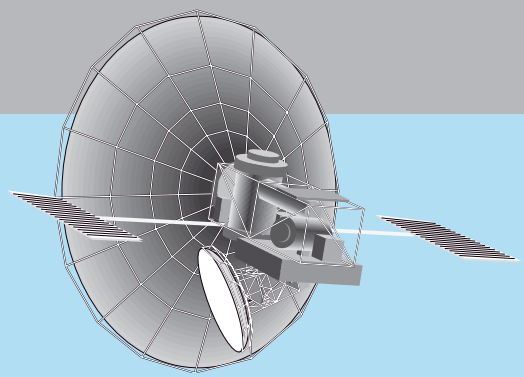


The spectacular failure of the first flight of the Ariane 5 launcher on June 5th proved just how vulnerable new launch technology can be. The accident is the worst in European space history, with a total estimated loss of US$500 million.

Compiled by GARRY CRATT*

Despite the loss, industry experts expect the long term effect on Arianespace will be small. Flight V501 was conducted by the European and French space agencies and carried four Cluster magnetospheric research satellites.

The successful launch of Palapa C2 on May 15 promises to breathe new life into Indonesia's satellite system. The C1 satellite, suffering some kind of power problem, presently radiates vertically polarised signals at a much lower level than was anticipated. The C2 satellite, observed in a test location of 124° E longitude during June, is destined to replace C1 as early as July at 113° E.

ASIASAT 2 – 100.5° E longitude: the 5-channel European bouquet of channels, marketed under the Deutsche Welle banner, began operation in late May. However, changes to the bitstream made in June, allowed the first reception on domestic MPEG 2 equipment. Presently, three of the five channels are operational, providing broadcasts from Germany, Spain and France. Yet to come on line are MCM (France) and Rai International (Italy). MPEG 2 decoders should be available by the end of July.

Meanwhile, several more analog signals have become available on this satellite at 1310MHz and 1425MHz IF. Both signals are broadcast in Mandarin.

Releasing expansion plans, Asiasat advise that their AS 3 satellite, carrying higher power transponders on both C and K band, will increase coverage by 16%. The satellite will be located at the same location as Asiasat 1 (105.5° E) which will be relocated to 122° E.

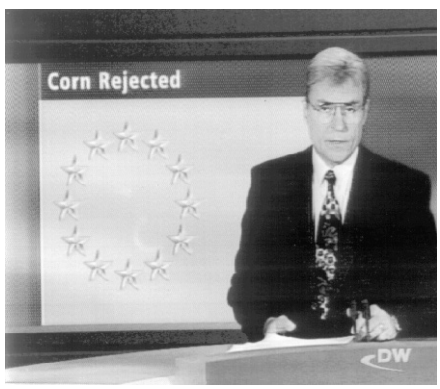
PALAPA C1 – 113° E longitude: although some improvement in signals levels of vertically polarised transponders has been reported by enthusiasts in Australia and New Zealand, levels are still below those originally predicted. The replacement of this satellite sometime in July should result in greatly improved signal levels. It is anticipated that parallel programming will operate on the C1 and C2 satellites for a few months after C2 location.

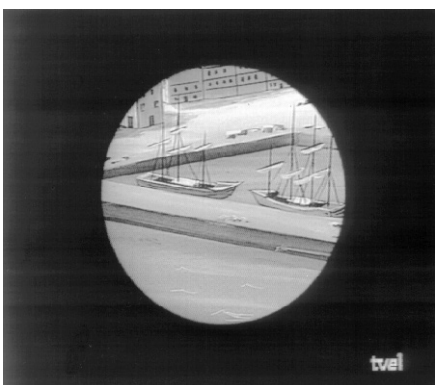
JCSAT 3 – 128° E longitude: after months of testing, Japan's newest DTH operator "PerfecTV" commenced an initial subscription drive in Japan. Whilst designed only to be received in Japan, the hardware cost for the 70-channel service is around US$700 and a three month free trial period will run from June to September. PerfecTV is a joint venture between Itochu Corp, Mitsui & Co. Ltd, Nissho Iwai Corp and Sumitomo Corporation.

Japan Satellite Systems has also ordered a 4th satellite from Hughes Space and Communications. JCSAT4 will be a HS601 satellite, similar to JCSAT3 and will carry data, voice and television signals to Japan and will be equipped with multiple beams covering India, Australia and New Zealand. The Eastern beam will cover Hawaii.

JCSAT1, which commenced operations in April 1989, will be retired in August this year, after the discovery of a fuel leak in March. The leak means that the satellite will be retired two years earlier than planned. As a temporary measure, JCSAT4 will be moved to 150 E longitude, the same orbital location as JCSAT1, to ensure that there is no service interruption. JCSAT1 is presently used for DTH broadcasting, news gathering services, VSAT, CATV and vehicle tracking operations.

GORIZONT 41 – 130° E longitude: Raj





These three screen shots are from the new 5-channel European service carried by Asiasat 2.

TV continues to be the only transponder viewable in Australia from this satellite. A 1.8-metre dish is sufficient for noise free reception anywhere along the east coast. The IF is 1465MHz and the polarisation is lefthand circular.

GORIZONT 42 - 142.5° E longitude: the latest channel to commence operations on this satellite is Indian broadcaster's "Global TV" adult channel, Channel 21. The nature of the programming and the type (if any) of encryption remains unknown. Typically, broadcasters will operate for several months "free to air" before offering subscriptions.

This brings the number of signals that can be seen across Australia from this satellite to three: EM TV New Guinea, Asia Music/Zee Education and Global TV. The IF for the global service is 1375MHz. All services operate lefthand circular polarisation.

PANAMSAT PAS-2 - 169° E longitude: July 1 saw the introduction of a new analog service on this satellite. Located at IF 965MHz, "The Value Channel" operates in NTSC and will remain unencrypted for the foreseeable future. The broadcaster offers domestic viewers the opportunity to purchase goods by telephone, using a credit card. For domestic viewers on the east coast of Australia, a 3-metre dish is recommended.

As part of the Panamsat upgrade to a DVB-compliant MPEG platform, a number of broadcasters, previously operating in the proprietary Scientific Atlanta MPEG 1.5 standard (such as CMT, ANB, CTN and CNBC) have been relocated to allow simultaneous operations in both MPEG1.5 and MPEG2. The 1.5 services were scheduled for deletion on June 30, subject to completion of the rollout of replacement D9223 IRDs. The new IFs for those broadcasters are: CMT, ESPN-2, BBC World, Bloomberg TV, 1249MHz horizontal and CNBC 1057MHz vertical.

INTELSAT 511 - 180° E longitude: this satellite is scheduled to be changed to Intelsat 701 (presently located at 174° E), operating in geostationary orbit, in late 1996. This will eliminate the need for the autotracking equipment now required for Intelsat 511. In recent months, there has been an increase in the number of broadcasters testing MPEG circuits on this satellite. **SC**

*Garry Cratt is Managing Director of Av-Comm Pty Ltd, suppliers of satellite TV reception systems.

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SERVICEMAN'S LOG

How many symptoms from one fault?

I believe it was Henry Ford who made the profound (?) statement that "history is bunk". But someone else, whose name escapes me, made the rather more realistic statement that "he who ignores history will be made to relive history".

What has all that to do with servicing TV sets? Well, it turned out to be singularly appropriate in regard to the story I'm about to relate, though I doubt whether either of the aforementioned philosophers was thinking of anything so trivial (to them) as TV servicing.

It all started with a Teac CT-M515S colour TV set, a 51cm model about three years old and featuring stereo sound, Teletext, and remote control. The owner's complaint was straightforward enough; it was completely dead. And so it appeared to be at switch-on – no sound, no picture and no light on the screen.

Until I advanced the brightness control, that is. Then the real symptom became obvious. There was no vertical deflection, the set displaying the classic thin bright line across the centre of the screen.

A routine voltage check immediately produced a vital clue – there was no 12V rail. The 12V rail is derived from pin 4 of the horizontal output transformer (T402) via a 0.68Ω fusible resistor (R423), diode D404, a 6.2Ω 3W resistor (R422), zener diode ZD402, and a 1000µF filter capacitor (C421).

The immediate cause of the supply rail failure was ZD402, which had broken down and taken out R422. But that was not all. The vertical output IC (IC401 - TDA2653B) had also been destroyed. Which had come first and destroyed which? There were no clues on this but I regarded it as of secondary importance anyway. More to the point, replacing those three components was all that was needed to get the set working again.

And it worked very well. I gave it a thorough once-over, made some minor setting-up adjustments, let it run for a couple of days, and then returned it to the customer. And that should have been the end of the story.

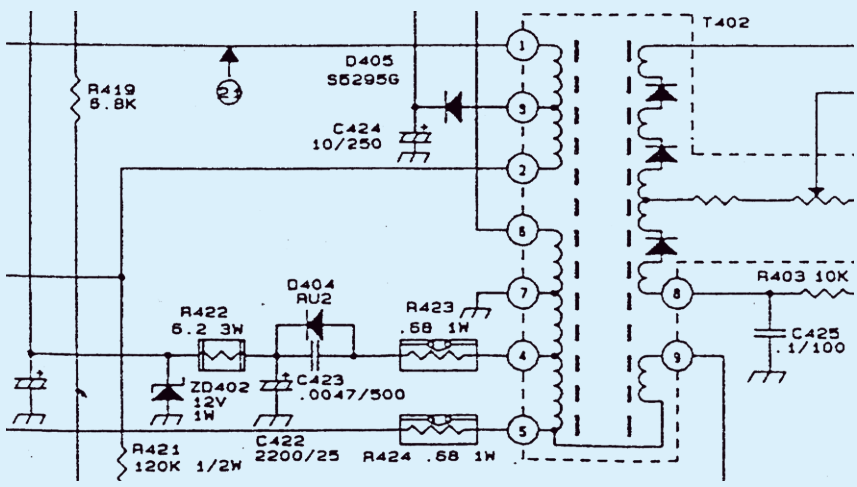


Fig.1: part of the horizontal output circuit in the Teac CT-M515S colour TV set. A 12V rail is derived from pin 4 of the horizontal output transformer, via 0.68Ω fusible resistor R423, diode D404, 6.2Ω resistor R422, zener diode ZD402, and 1000µF filter capacitor C421.

Here we go again

It wasn't, of course. A month went by and the set was back in the shop. Well, that was bad enough but the really nasty part was that it was the same components which had failed. Which meant that I had treated only the symptoms, not the cause. And I had to find the cause.

I replaced all the damaged components again (it was becoming a costly exercise) and the set came back to life. But of course I couldn't leave it at that; I had to find what caused all this destruction.

In general terms, I suspected an over-voltage condition of some kind, either high amplitude short term, or lower amplitude continuously. I couldn't do much about checking for the former but at least I could check the latter.

So I made a complete voltage check, looking for any values which were even marginally high. This achieved nothing directly; all values were virtually spot on.

But it did help indirectly, even though I did the right thing for – initially – the wrong reason. While making these checks, I paid particular attention to the high tension rail. This rail is derived from pin 5 of the switchmode transformer (T901) via D904 and normally sits at 113V, as measured at test point TPB+.

However, between diode D904 and TPB+ there is a network of three transistors: Q907 which is directly in the HT rail line, Q906 which controls Q907, and Q905 which controls Q906.

I didn't recognise this network immediately. I assumed it was a voltage regulator and, on this basis, wondered whether a fault here could have been responsible.

I was clutching at straws but decided to check all three transistors. And I struck oil! Q907 was short circuit. But gratifying though this was, it didn't altogether make sense. If it had ceased to function as a voltage regulator, why did the rail still measure 113V? Why hadn't it gone high?

I took another look at the network and realised my mistake. It wasn't a voltage regulator at all. Instead, it was a switching network, used to switch the set on and off via the remote control system.

In greater detail, the switchmode supply runs continuously while ever the mains supply is on. The remote control switches Q905 which in turn switches Q906 and ultimately Q907 in the HT rail to turn the set on and off. In addition, the remote control switches various signal paths.

It would be no problem to replace the transistor but would this bring me any closer to the real problem? Well, it did. Deep down in the brain cells, something stirred. Mr Ford's disparaged history was proving to be anything but "bunk". Rather, a whole lot of historical bits were coming together. So much so that I began deriding myself for not realising sooner what might be wrong.

I went straight to C909, a 47µF 25VW electrolytic on the base of switching transistor Q904 in the power supply, and reefed it out. I replaced it with a high temperature, higher voltage type and modified the mounting somewhat to keep it as clear as possible from heat sources.

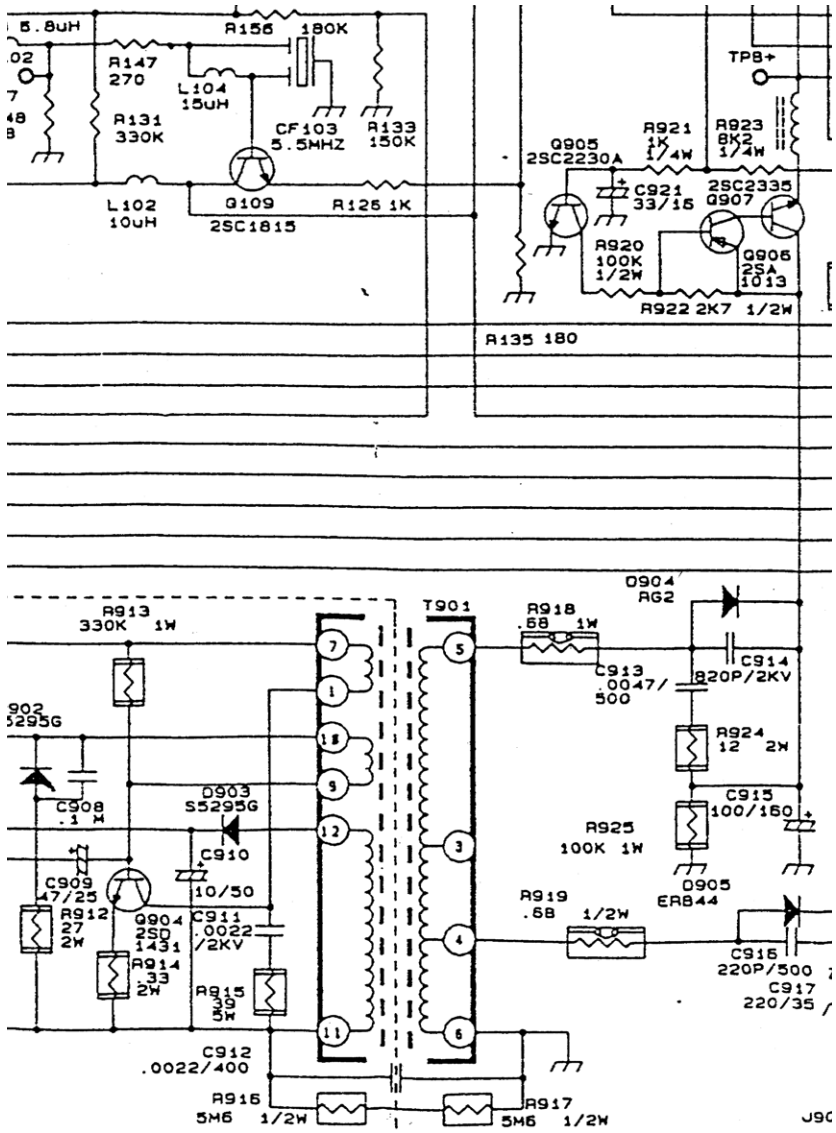


Fig.2: the switchmode power supply in the Teac CT-M515S. The HT rail comes off pin 5 and goes to switching resistor Q907 at top right. C909 is at lower left.

Been there, done that

So what was the connection? This switchmode power supply is virtually identical to one produced by Siemens many years ago – almost back to the beginning of colour TV in Australia – and which has been used by many manufacturers since then. It was used in some early HMV receivers (C211, C221 series, etc) and more recently in the Fujitsu-General FT-1411 and FT-2011 receivers and the Sanyo CTP6626, among others.

And it was memories of the Fujitsu-General FT-1411 which stirred first. It all happened many years ago and, what with my memory cells being somewhat sluggish these days, I had completely forgotten it. But as I recall it now, the complaint was that it could not be switched off properly via the remote control.

And I use the customer's term "properly" because, while there was no picture, there was still a raster on the screen; ie, full line structure but no video. It looked a simple enough problem initially. The setup was almost identical with that of the Teac – a transistor (Q606) in the HT rail (109V), controlled in turn by Q605 and Q608, the latter fed from the remote control system. And Q606 had gone short circuit. (As an aside, Q606 was a type 2SC2335, which is the same type as Q906 used in the Teac).

Anyway, the problem was easily fixed – a new 2SC2335 and the set was back to normal. The trouble was, the set bounced. I thought it was just bad luck the first time but when it bounced again I knew I was in strife.

I won't bore the reader with all the details as to how I finally cracked it but, as I recall, it was a combination of good luck and some physical evidence. The physical evidence was signs of corrosion around two electrolytics in the power supply, C607 and C620, both 100µF/25V. They were connected in series to give 50µF and fed the base of the switching transistor, Q604, in

the same manner as C909 in the Teac.

I can't explain the reason for the series arrangement. If it was to increase the voltage rating, it wasn't a very good effort; there was no resistor network to equalise the voltage distribution. Anyway, I substituted a 47µF capacitor with a higher voltage rating and a high temperature rating and that finally solved that problem.

Then there was the Sanyo CTP6626 which uses an 80P chassis (or more correctly, there were several sets with the 80P chassis). And, once again, this uses what is virtually a Siemens type switchmode power supply. In fact, this story goes back even further and would have been my first encounter with this particular fault.

In this case, however, the story of one fault is essentially the story of them all. Apart from minor variations (some sets were intermittent), they all produced the same symptoms from the same fault. It was real beaut at the time because I quickly learned to handle the situation. But it did little to prepare me for the variations on the theme which occurred in the Fujitsu-General and the Teac several years later.

In essence, the problem presented itself as a destroyed horizontal output transistor (Q451), caused by a dramatic rise in the main HT rail due, in turn, to the failure of capacitor C314. C314 was a 47µF electrolytic capacitor in the power supply and fed the base of the switching transistor (Q304). And, in some cases, Q304 would also be destroyed.

Replacing the faulty transistors and substituting a high temperature electrolytic, mounted as far away as possible from any sources of heat, was all that was needed to put the sets back in operation and minimise the recurrence of the fault.

Which is pretty much where we came in. And, no Mr Ford, history isn't bunk; it's a very good teacher.

The money-hungry customer

My next story, as fate would have it, is also about a Sanyo TV set: a fairly old set, a model CCC-3000, a 34cm "Cosmo" portable, using an 80P chassis and, yes, the same Siemens type power supply. But the story is just about as far removed from the power supply problems as it could be.

The customer was a European gentleman with only a limited grasp of English. But his grasp of money matters suffered no such limitation; he was as sharp as they come. So this story is nearly as much about customer relations, charges and the eternal problem of quotes, as it is about technical problems. Inevitably, of course, the two are interwoven.

The basic problem was simple; the set had been dropped. Not particularly hard apparently – there was no obvious external damage – but enough to put it out of action.

Right from the start, and simply on the basis that the set had been dropped, the gentleman wanted me to quote him to repair it. As a basic rule, I don't quote for repairs and certainly not on the basis of such vague information. I will try to assess a particular situation, based on the best available evidence, but at best this is a guestimation. There must inevitably be a number of "ifs" and "buts" included in such an assessment.

As a colleague once put it, "you don't really know what a job is going to cost until it's finished – and it's a bit late then to quote for it." An exaggeration? Perhaps, but there is lot of truth in that too.

Anyway, I explained that could not quote him for the job and set out some of the reasons. I told him I charged so much an hour for labour, plus the cost of any components which had to be replaced.

The best I could do was switch the set on and try to assess how much damage had been done and, therefore what kind of cost might be involved. And, as I pointed out to him, I didn't even know whether the picture tube was still working.

This didn't seem to make much

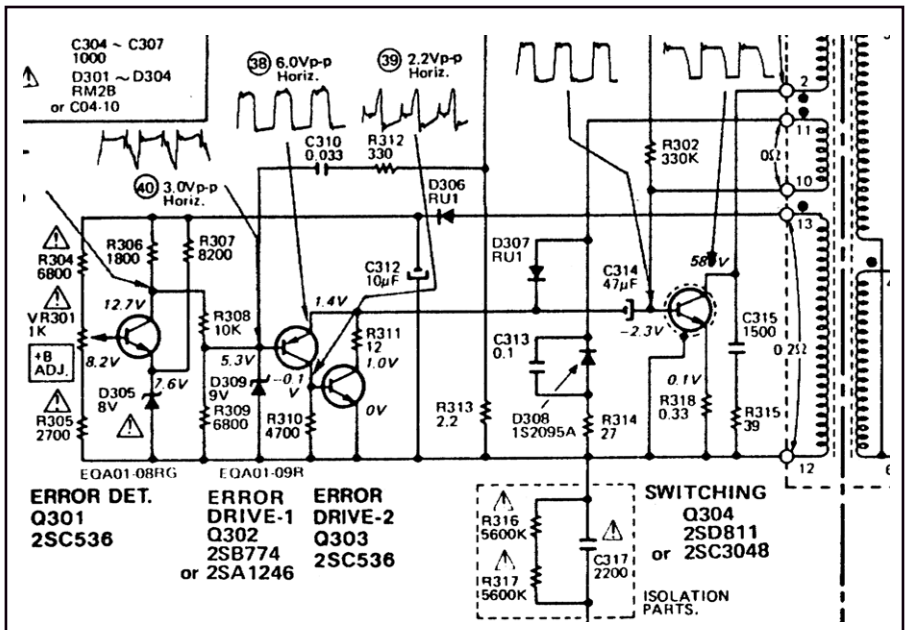


Fig.3: the switchmode power supply in the Sanyo 80P chassis. It's similarity to the Teac supply is evident, both being based on an early Siemens circuit.

impression but I switched the set on anyway. The result was more promising than I had expected. The sound came up immediately and, as the tube warmed up, there was some signs of life on the screen – a bright horizontal line. Well, this meant that the tube was intact, the power supply was working, and the horizontal output stage was working. In fact, most of the vital parts were working except the vertical output stage.

On this basis, I told him that I thought the most likely fault was a cracked board. I couldn't say how serious this might be. It might be possible to repair it or, if it was too badly damaged, the only alternative would be to replace it – assuming a replacement was available and the cost could be justified.

My most favourable assessment, therefore, was that it would involve at least two hours work. And that assumed that no components had to be replaced, which I felt was a fair bet.

That still wasn't good enough; he insisted that I open the set, on the spot, determine the exact nature of the damage, and give him a firm quote for a repair. I was equally insistent that this was out of the question and that the situation was not negotiable; take it or leave it.

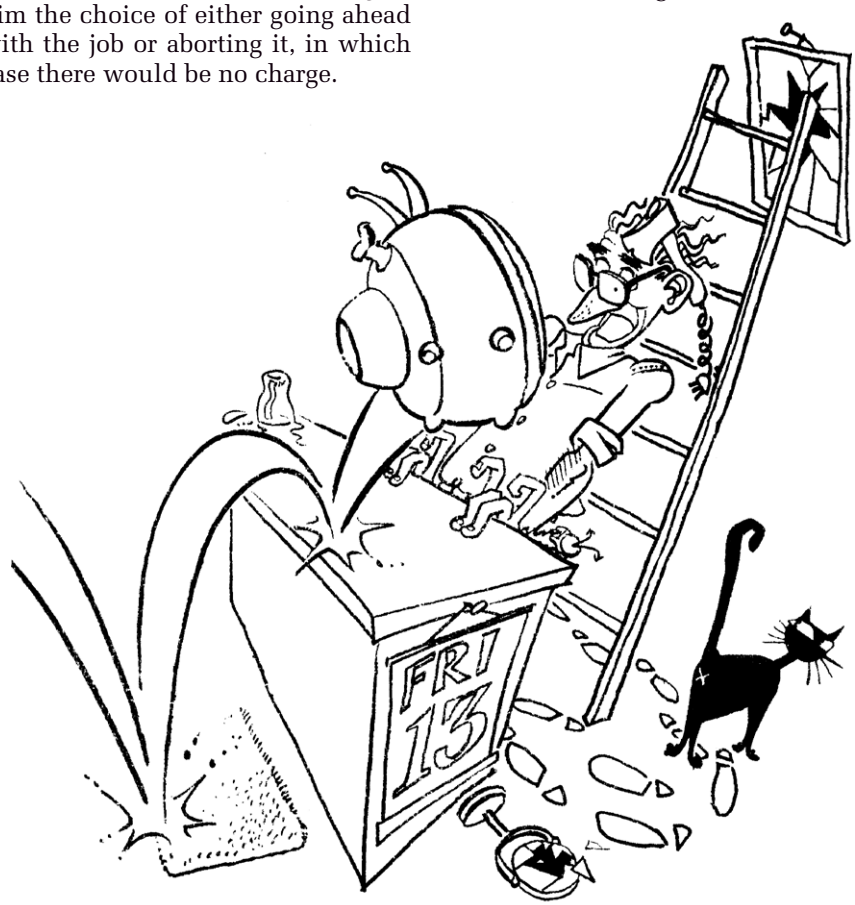
He hummed and hawed about this but we finally reached a compromise. I agreed to quote him for two hours labour. If the job was going to cost more than that I was to contact him and give him the choice of either going ahead with the job or aborting it, in which case there would be no charge.

I wasn't particularly happy with this arrangement but felt fairly confident that I could work within it. So it was on to the bench and off with the back. My immediate impression was that it had obviously spent most of its life near the ocean, because there was considerable corrosion on the metal parts.

But I was looking for cracks. There was nothing immediately obvious and I removed the main board for a closer inspection. The high risk areas would be near the horizontal transformer and where the board is supported by the cabinet.

And this was where I found it; from the transformer to the edge of the board. It was a very fine crack, about 10cm long, and not at all easy to see. In fact, I suspected that at least some of the copper tracks were still be functioning, though obviously not very reliably.

Anyway, it looked like a fairly straightforward job, despite the fact that a number of tracks were broken. There was a fair amount of work involved in cleaning the board of dust



and grime, plus the original green varnish, until I was back to bright copper. Then it was simply a matter of flowing solder over the breaks.

Sometimes, if a crack is bad enough, I fit a wire bridge but I didn't consider it necessary in this case. In fact, the end result was very satisfactory, both visually and mechanically.

The big test

Unfortunately, when I switched it on, the result wasn't satisfactory at all; the vertical deflection stage was still not working. My first reaction was to suspect that a supply rail had been lost, perhaps because of a crack I had missed.

I pulled out the circuit diagram and began checking all the rails which, at least at their starting points, appeared to be correct. So I began tracing them. And, since I don't like running a set for long periods with a fault like this, I would switch it on briefly, check a voltage, then switch off while I lined up another check point.

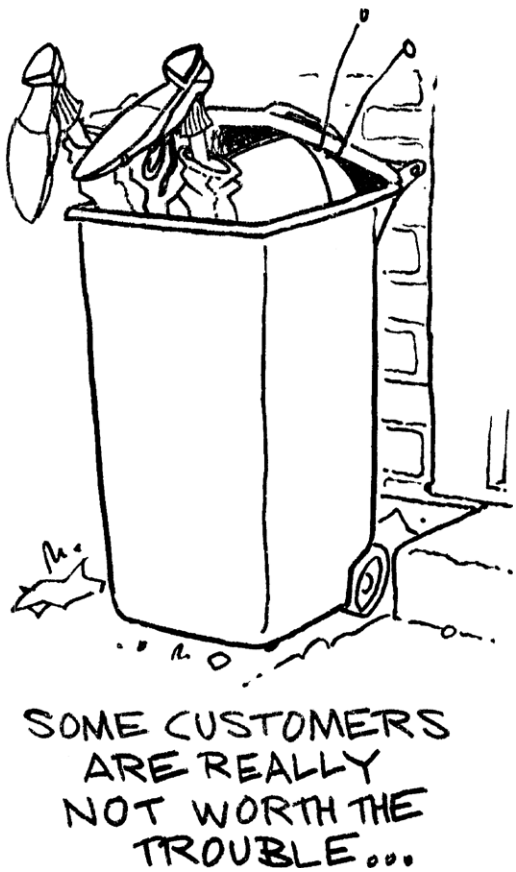
Then suddenly, when I switched the set on, the white line had vanished. And not because I'd cured the fault but because the set was now completely dead. This was a really revolting development; instead of finding the fault I had seemingly created another one.

I went over the board again, looking for any missed cracks, but drew a blank. There was still the full 110V on the main HT rail from the power supply but no secondary voltages from the horizontal output transformer. And the CRO confirmed that there was no horizontal activity of any kind; nothing at the output stage (Q451) and nothing at the driver stage (Q450).

Further checks revealed that the voltage on Q450's collector was high. Instead of the indicated 64.7V, it was sitting at the full rail value of 110V. It was obviously turned off and the CRO confirmed that it was not being driven from pin 3 of IC401, which contains both the horizontal and vertical oscillators.

So why wasn't IC401 working? This IC takes its voltage from the 110V rail via a 6.8kΩ resistor (R410) to pin 15, which is marked as 12.7V. And this voltage was spot on.

There wasn't much left to suspect, except the IC itself. Had I destroyed it in some way while making tests? I hoped not but the only way to prove the point was to replace it. I pulled it out and, because of possible doubts about my diagnosis, fitted a socket to the board and plugged in a replacement IC.



And that fixed it. Not only did the set come back to life when switched on but the vertical scan had also been restored and we had a full picture on the screen.

Unanswered questions

All of which leaves a lot of unanswered questions. If the vertical failure was due to a fault in IC401, rather than the crack in the board, what had caused it to fail?

Was the set running when it was dropped and was there a voltage surge when the copper tracks fractured? And why were there no other symptoms due to the cracks?

Without backtracking and identifying every broken track, I can only guess. However, it is possible that there were other symptoms which were masked by the vertical failure. There may have been no video or no colour, for example.

And why did IC401 then suffer a further failure? This may have been due to my test routine but I don't think so. Closer examination of the IC revealed quite a lot of corrosion on the pins, particularly where they enter the plastic body. The pins were firm enough mechanically but it's possible that some corrosion had made its way inside the body.

As a check, I refitted the original IC in the socket and gave it a bit of a bashing for good measure. But it was completely dead. As I say, these are questions for which I have no answer.

Ungrateful customer

More to the point, in practical terms, the job had now gone outside the terms of the cost agreement. As well as the two-hour labour charge – which had been exceeded but which I would carry – the customer was now up for an extra $20 for the IC.

Sticking to the agreement, I rang him and advised him of the situation. More aggro; he didn't want to go beyond the original labour charge. I refused to budge. I pointed out that I had kept my part of the agreement and it was up to him to keep his. And I added the clincher – if he didn't want to pay the extra $20 I would put the old IC back in the set and he could come and collect it, no charge.

That did it. Knowing that I had the set running on the bench but that I could easily disable it was too much. He agreed to pay the extra charge, albeit reluctantly.

It was over a week before he turned up and during that time the set never faltered. But would you believe it, when he came to collect it, he tried to beat me down again.

I didn't even argue with him; I made it clear it was take it or leave it. He took it – and I hope I don't see it or him again. Some customers are really not worth the trouble. **SC**

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Previously a neglected field, power electronics has come into its own, particularly in the areas of traction and electric vehicles. F. F. Mazda is an acknowledged authority on the subject and he writes mainly on the many uses of thyristors & Triacs in single and three phase circuits. 417 pages, in soft cover at $59.95.

Electronics Engineer's Reference Book

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Edited by F. F. Mazda. First published 1989. 6th edition.

This just has to be the best reference book available for electronics engineers. Provides expert coverage of all aspects of electronics in five parts: techniques, physical phenomena, material & components, electronic design, and applications. The sixth edition has been expanded to include chapters on surface mount technology, hardware & software design, semicustom electronics & data communications. 63 chapters, in hard cover at $120.00.

Radio Frequency Transistors

Principles & Practical Applications. By Norm Dye & Helge Granberg. Published 1993.

This book strips away the mysteries of RF circuit design. Written by two Motorola engineers, it looks at RF transistor fundamentals before moving on to specific design examples; eg, amplifiers, oscillators and pulsed power systems. Also included are chapters on filtering, impedance matching & CAD. 235 pages, in hard cover at $85.00.

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By Rudolph Strauss. First published 1994.

This book will provide informative reading for anyone considering the assembly of PC boards with surface mounted devices. Includes chapters on wave soldering, reflow soldering, component placement, cleaning & quality control. 361 pages, in hard cover at $99.00.

Audio Electronics

By John Linsley Hood. Published 1995.

This book is for anyone involved in designing, adapting and using analog and digital audio equipment. Covers tape recording, tuners & radio receivers, preamplifiers, voltage amplifiers, power amplifiers, the compact disc & digital audio, test & measurement, loudspeaker crossover systems and power supplies. 351 pages, in soft cover at $52.95.

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Are your TV signals weak or noisy? This masthead amplifier could mean the difference between a lousy picture and good reception.

Portable masthead amplifier for TV & FM

By BRANCO JUSTIC

THIS MASTHEAD AMPLIFIER was originally designed for use with caravans and recreational vehicles. It's portable, comes with its own inbuilt telescopic (rabbit ears) antennae and runs off a power supply ranging from 7-20V DC or 6-15V AC. This means that you can either power the unit from a 12V car battery or from the mains via a suitable plugpack supply.

The "rabbit ears" telescopic antennae feed directly into the amplifier circuit. This circuit typically provides from 16-20dB of gain at frequencies up to 1GHz, which should be plenty for beefing up an otherwise marginal signal to a portable TV set.

If you're fed up with constantly adjusting the antenna on your portable TV set or if the reception varies when you change channels, this "active" antenna system is the way to go. It not only amplifies the incoming signal but, just as importantly, provides correct impedance matching between the antenna and your TV set.

Of course, there's nothing to stop you from using this design in fixed installations or as a distribution amplifier. All you have to do is ditch the rabbit ears antennae and feed a signal in directly from a fixed antenna or a distribution cable. The unit is easy to install and is suitable for amplifying both VHF and UHF signals, as well as FM signals.

As with most masthead amplifiers, the DC supply rails are delivered via the downlead; ie, the TV signal and the supply rails share the same cable. This means that you don't have to run separate supply leads up the mast, which greatly simplifies the installation.

Generally, the best approach is to mount the amplifier as close to the antenna terminals as possible. That's

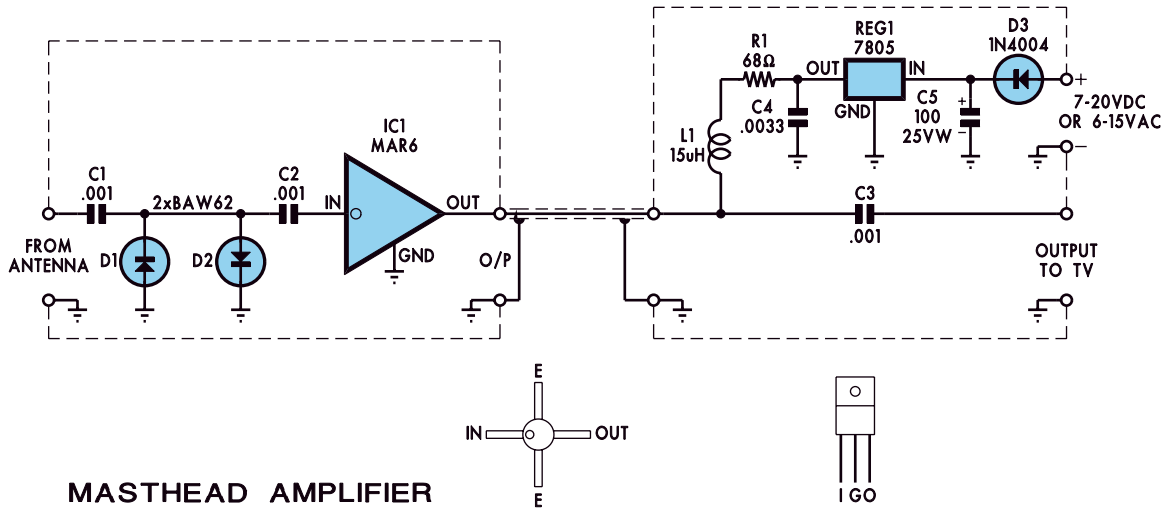


Fig.1: the circuit is based on a MAR6 broadband RF amplifier (IC1) which provides around 20dB of gain. D1 and D2 protect the input of IC1 by clipping any high voltage transients, while REG1 provides a 5V supply rail. This supply rail is fed via the signal cable to the output terminal of IC1 and is isolated from the TV set using C3.

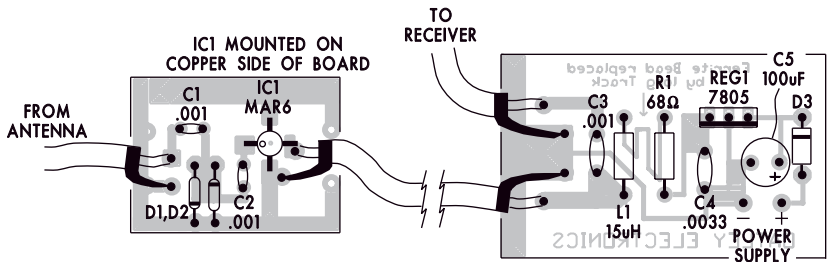


Fig.2: install the parts on the two PC boards as shown here. The MAR6 (IC1) is mounted from the copper side of the board (see photo).

really just another way of saying that it should go on the mast. This is done to avoid signal degradation due to cable losses. Quite often, a good signal is available at the antenna terminals but cable losses can result in a severely degraded signal by the time it reaches the TV set.

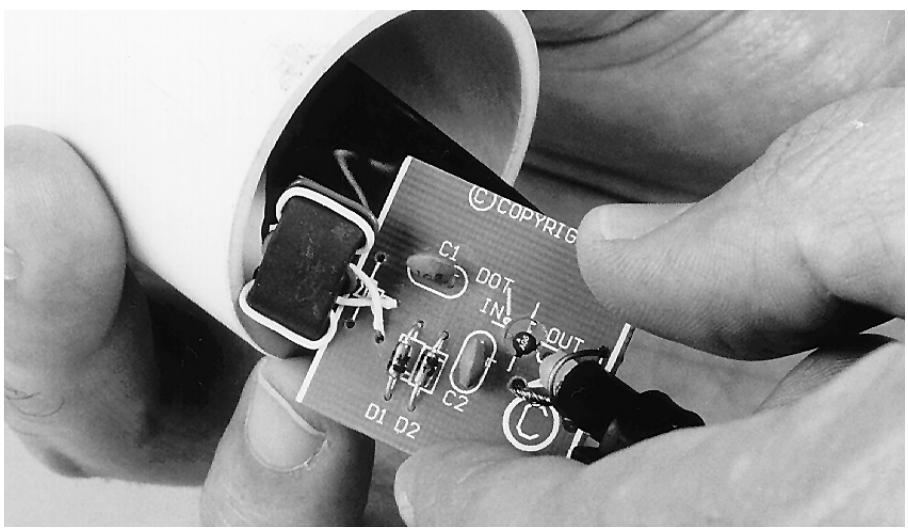
The basic idea is to amplify the good signal that's coming from the antenna, rather than a noisy signal at the TV set itself.

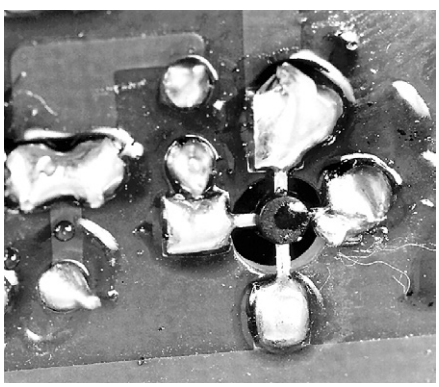
Well, that's what the theory says. In practice, you can sometimes get a good result by placing the masthead amplifier at the TV if you don't want to go to the trouble of mounting it on the mast. This only applies to borderline situations, where the signal is just too weak for the AGC (automatic gain control) circuit to limit the front-end gain of the receiver.

In this situation, you get a "snowy" picture because the front-end operates at high gain which results in a poor signal-to-noise ratio. By amplifying the signal before it is fed into the receiver's front end, the AGC circuit limits the gain and this drastically cuts the noise to give a clear picture.

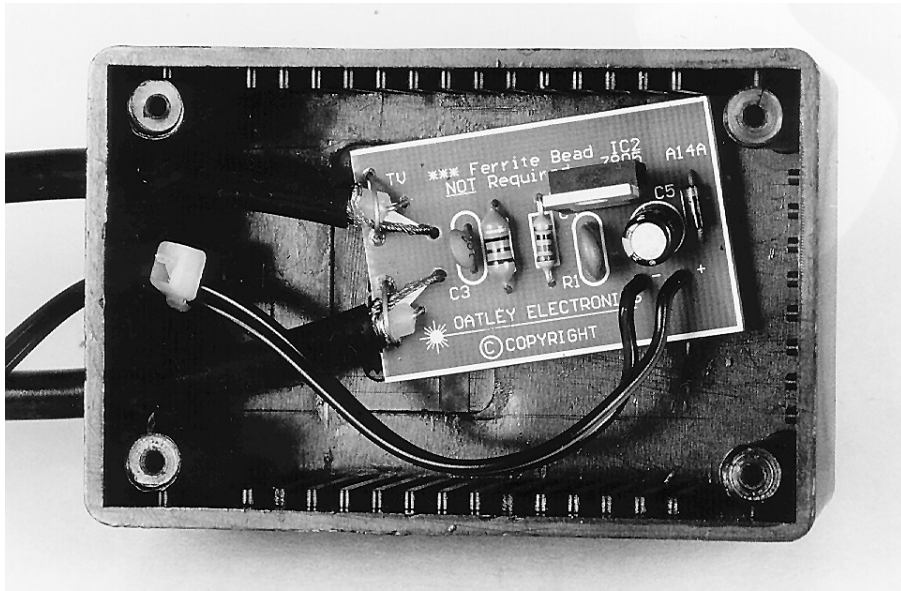
Distribution amplifier

Another area where this circuit should prove popular is as a distribution amplifier. Quite often, a signal that's adequate for one TV set will no longer be adequate when fed through a splitter for distribution to several outlets. That's because the splitter itself introduces signal losses, typically around 3.5dB or more.





The amplifier board (left) is installed inside a length of 100 x 43mm OD conduit. Above is a close-up view of the MAR6 IC, which is mounted on the copper side of the board.



The power supply board is installed inside a small plastic utility case, as shown here. Take care to ensure that the 7805 regulator is oriented correctly and check that the completed unit delivers +5V to the centre conductor of the lead that runs to the amplifier board.

The answer is to amplify the signal before feeding it to the splitter. Doing this will ensure a sufficient level at each outlet for a noise-free picture, despite losses in the splitter circuit and the distribution cable.

Circuit details

Fig.1 shows the circuit details. It's based on a MAR6 monolithic broadband amplifier (IC1) made by Mini-Circuits (USA). This device has a rated bandwidth from DC to 2GHz, 20dB of gain at 100MHz and a low noise figure of around 2.8dB. This noise figure is far superior to the noise figure for the OM350 monolithic amplifier used in many older masthead amplifier designs.

Apart from the MAR6, there's just a 7805 3-terminal regulator, three diodes and a few minor components. All the required gain is provided by the MAR6, so there's no need to make things complicated. Let's take a closer look at how it works.

The signal from the antenna is coupled to the input of IC1 via capacitors C1 and C2 which provide DC isolation. Diodes D1 and D2 are there to protect IC1 from excessive input voltages, as could be induced by nearby RF transmitters, lightning strikes or static build-up.

Note that BAW62 diodes are specified here, as these are a high-speed switching type with very low capacitance. As a result, they provide good protection for IC1 with very little signal loss. In operation, they clip any high voltage spikes to ±0.6V.

The amplified signal appears at the output of IC1 and is coupled directly to the centre conductor of the coaxial cable downlead. It is then subsequently fed to the antenna terminal of the TV set via C3.

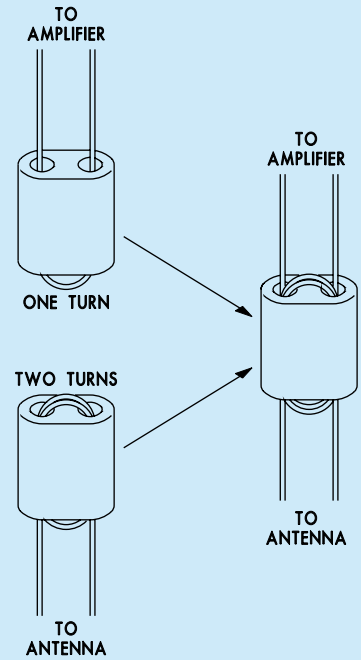


Fig.3 a balun is necessary if you intend using the twin telescopic antenna. It is wound using light-duty single core wire.

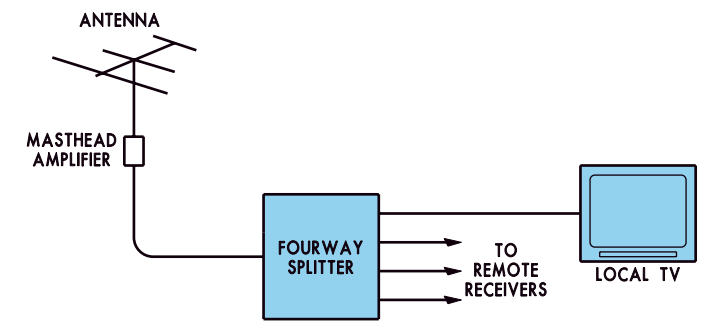


Fig.4: a masthead amplifier is useful for boosting the signal before it is fed to a splitter for distribution to multiple TVs.

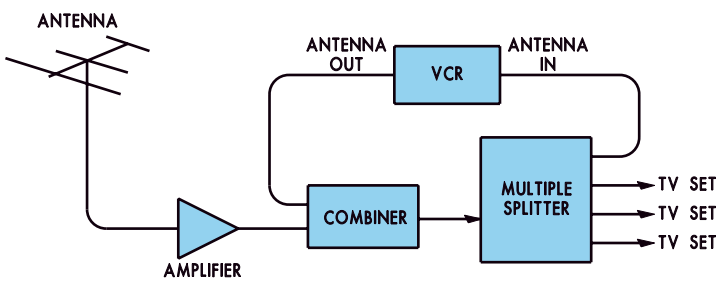


Fig.5: here's how to include a VCR in a distribution system. The combiner is just a 2-way splitter wired back-to-front.

Power supply

Power for the circuit is derived from an external AC or DC plugpack supply. D3 either rectifies the AC supply or, in the case of a DC supply, provides

Do You Need A Masthead Amplifier?

"Will a masthead amplifier solve my TV reception problems?"

That's a question that's often asked and the answer is "it depends". A masthead amplifier is not a universal panacea for crook TV pictures and there are many situations where it will offer little or no improvement. It will not eliminate most ghosting problems, for example, as the ghosts just get amplified along with everything else.

Nor can a masthead amplifier clean up interference problems or give you a good picture if there is little or no signal in the first place.

That said, there are many situations where a masthead amplifier can dramatically improve picture quality, particularly in fringe areas. Basically, you should use a masthead amplifier under the following circumstances:

(1) You live in a fringe area and one or more channels is noisy;

(2) Reception is poor due to losses in the downlead;

(3) The signal strength is inadequate because of splitter and cable losses in a distribution system;

(4) The antenna system is only very modest.

reverse polarity protection. The resulting DC rail is then filtered by C5 and drives 3-terminal regulator REG1. The 5V output from REG1 is then filtered and applied to the output terminal of IC1 via R1, L1 and the centre conductor of the downlead.

Inductor L1 presents a high impedance at signal frequencies and thus ensures that IC1's output is not loaded by the supply rail. It also serves to keep signal frequencies out of the regulator output circuitry.

Construction

The assembly of the masthead amplifier is straightforward, with all the parts mounted on two small PC boards. The MAR6 RF amplifier and its associated parts go on the smallest board and the completed assembly installed inside a length of 100 x 43mm OD plastic conduit. This is fitted with end caps for weatherproofing – an important consideration if the unit is to be mounted outdoors on an antenna mast.

The power supply parts are accommodated on the second board. This board fits inside a small plastic utility case which would normally be hidden somewhere behind the TV set.

Fig.2 shows the parts layout on the two PC boards. Begin by installing the parts on the amplifier board, taking care to ensure that diodes D1 and D2 are oriented in opposite directions. The two capacitors are non-polarised and can be installed either way around.

The MAR6 amplifier IC is a surface mount device and is installed from the copper side of the PC board. The accompanying photographs show how this is done. Make sure that it is correctly oriented. Its type number should be visible from the component (top) side of the PC board, while a small white triangle or dot indicates the input pin.

If you are using 75-ohm coaxial downlead from the antenna, this can be soldered directly to the PC board as shown in Fig.2. Alternatively, the rabbit ears antenna comes with 300-ohm ribbon cable and so a balun is necessary to match this (and other standard antennas which don't already have a balun) to the 75-ohm input impedance of the amplifier.

Fig.3 shows the winding details of the balun. It is wound using light duty single core wire. The amplifier side consists of a single turn through the core, while the antenna side consists of two turns wound from the opposite end of the core.

On the prototype, the rabbit ears antenna was mounted on one of the end caps (see photo) and secured using machine screws and nuts. Once

PARTS LIST

1 amplifier PC board (Oatley Electronics)
1 power supply PC board (Oatley Electronics)
1 twin telescopic antenna (optional)
1 balun core
1 100mm length of 43mm O.D. plastic conduit
2 43mm I.D. end caps
1 plastic case, 84 x 54 x 30mm
4 plastic cable ties
1 15µH inductor (L1)
1 68Ω resistor (0.25W)

Semiconductors

1 MAR6 wideband RF amplifier IC (IC1)
1 7805 3-terminal regulator (REG1)
2 BAW62 fast switching silicon diodes (D1,D2)
1 1N4004 silicon diode (D3)

Capacitors

1 100µF 25VW PC electrolytic (C5)
1 .0033µF ceramic (C4)
3 .001µF ceramic (C1,C2,C3)

Miscellaneous

Light-duty single core wire (to wind balun), clamps, silicone sealant, coaxial cable.

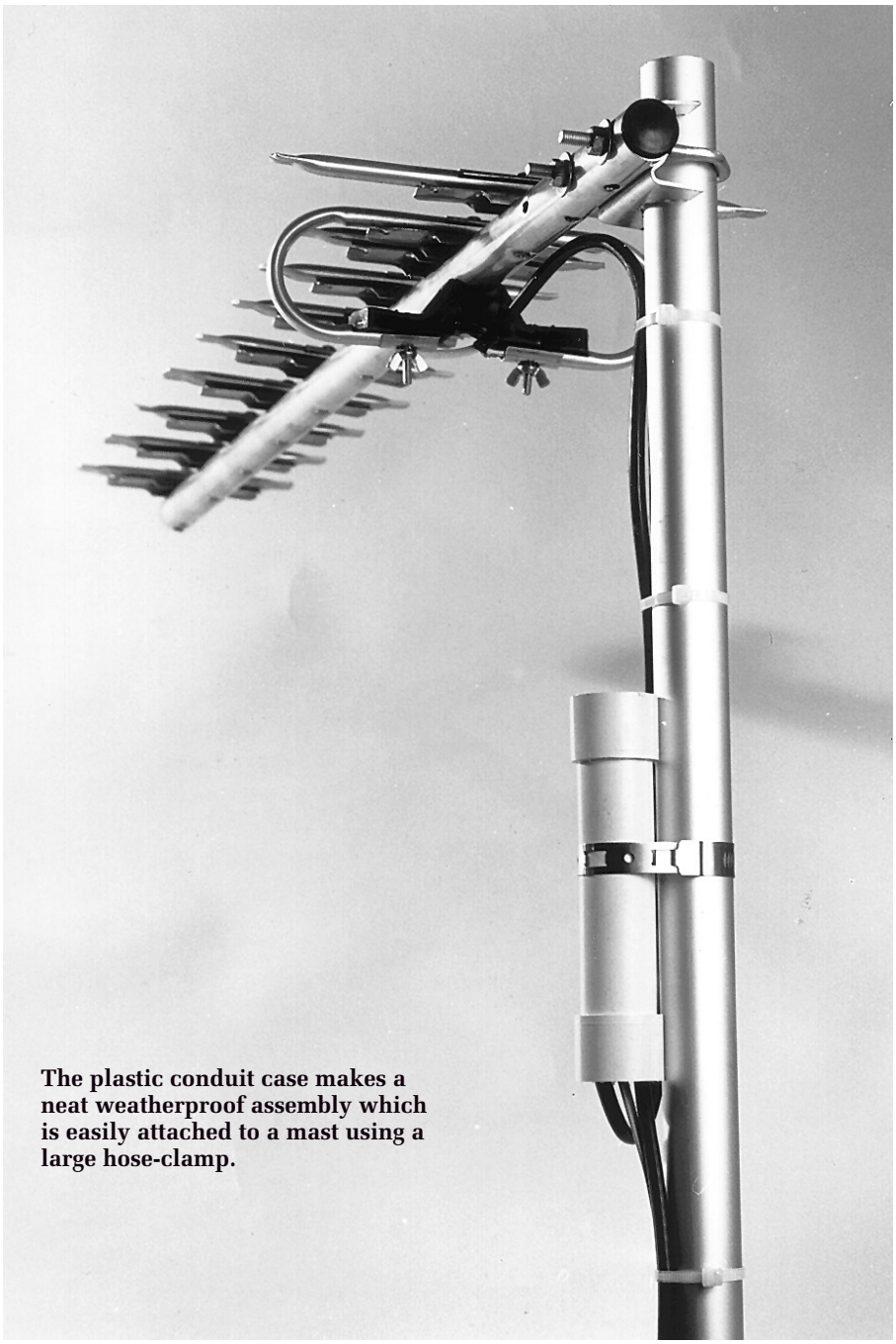
Where To Buy The Parts

Parts for this masthead amplifier design are available from Oatley Electronics, 5 Lansdowne Parade, Oatley, NSW 2223. Phone (02) 579 4985 or fax (02) 570 7910. Prices are as follows:

Basic kit (incl. PC boards, MAR6 IC, all on-board parts & balun core) ...$15.00
Twin telescopic antenna $5.00
Plastic case for power supply $2.50
Plugpack supply $10.00
RG59 coaxial cable 90c/metre

Payment may be made by cheque or credit card. Please add $5 for packaging and postage.

Note: copyright of the PC board artworks associated with this design is retained by Oatley Electronics.



The plastic conduit case makes a neat weatherproof assembly which is easily attached to a mast using a large hose-clamp.

the connections have been made, the completed amplifier board is pushed into its plastic conduit housing. The output lead emerges through a hole drilled in the bottom end cap.

For a fixed installation, the 75-ohm antenna lead is fed in through a second hole in the bottom end cap. It's a good idea to fit a couple of cable ties to the cables just inside the end caps to provide strain relief for the soldered connections. The two entry holes can later be sealed with silicone sealant after the assembly has been completed and tested.

The power supply board can now be assembled and tested. Take care to ensure that D3 (1N4004), C5 and REG1 are all correctly oriented. Inductor L1 (15µH) looks like a resistor. It has a light green body and carries brown, green, black and silver colour bands.

Once the power supply board has been completed, temporarily apply power and check that the output side of L1 is at +5V with respect to ground. If there's a problem here, switch off immediately and carefully check the circuit around REG1 and D3.

Assuming that all is well, the board can now be installed in its case and the external connections made. You will need to drill holes in one end of the case two accept the two coaxial cables and the power supply leads. As before, attach cable ties to the various leads just inside the case so that they cannot be pulled out.

Although not shown on the prototype, we recommend that the power supply leads be run to a suitable jack socket mounted on the end of the case. That way, the plugpack supply can be easily disconnected and used in another application if required.

Installation

The way in which the unit is used as an active antenna for portable TV sets is obvious – just unplug the existing antenna and plug this unit in instead. Don't forget to apply power to the amplifier though.

For use with an outdoor antenna, the amplifier unit should go up on the mast as mentioned previously. This arrangement will provide the best signal-to-noise ratio although a short length of high-quality coaxial cable between the antenna terminals and the masthead amplifier shouldn't make too much difference.

If used as a distribution amplifier, the unit can be mounted indoors, provided that input signal from the antenna is noise-free in the first place.

The output of the amplifier is connected to the splitter input and the splitter outputs then run to the various TV receivers. Fig.4 shows the basic idea.

Finally, if strong signals on one or more channels cause receiver overload (as indicated by an interference pattern), try fitting a tuned attenuator for the offending channel(s). This should be fitted right at the antenna terminals (ie, before the masthead amplifier).

A 1/4-wave stub makes a very effective tuned attenuator. This is simply a length of coaxial cable cut to exactly a 1/4-wavelength of the offending channel. If the stub attenuates the signal too severely, try making it slightly shorter until you get the desired result.

Another approach is to initially cut the stub slightly shorter than 1/4-wavelength and then tune it towards resonance using a trimmer capacitor across the far end. Just keep on experimenting until you get it right. **SC**

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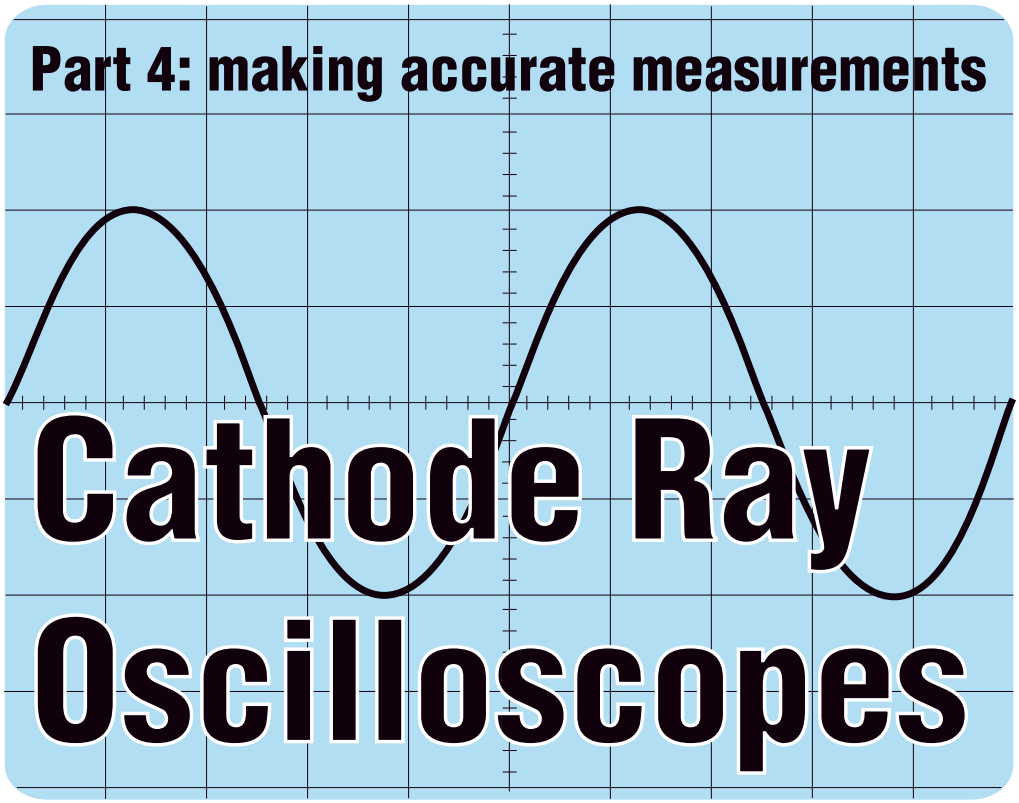


The oscilloscope is a wonderful measurement tool but if it is not used carefully it can give highly misleading results. You can achieve the full potential of your scope but only if you know what you are doing. This article gives some good tips on oscilloscope use.

By BRYAN MAHER

Say you have invested hard cash in a good quality oscilloscope. It looks a beautiful instrument and the specs guarantee it to be accurate within 2%. Wow! And its bandwidth is wide enough to make your friends drool.

But a scope is only a tool, no matter how glossy the literature. If you don't use it properly you will be disappointed with the results.

Let's start with a simple DC measurement, using the circuit shown in Fig.1(a). If we read the DC voltage at point D, a digital voltmeter (DVM) gives a reading of +4.9V. If we then connect the oscilloscope via a 1x shielded probe, the deflection on the screen is likely to indicate only about +4.17V. Which is correct? Clearly that scope probe is loading the source of this measurement, pulling the voltage down!

"Source" here means any part of circuit at which we make a measurement. In this case it is point D in Fig.1. And "source resistance" or "output resistance", denoted by Rs, means the ratio of the change in voltage at that point (caused by attaching the probe) divided by the minute current drawn by the probe.

This is denoted by the expression:

$$Rs = (\Delta v/\Delta i)\ \Omega.$$

Because it is a voltage/current ratio, we call it resistance (ohms), even though it is a calculated quantity. Only rarely is Rs a single physical component. Nevertheless Rs does have the ability to upset the workings of a circuit. "Delta" simply means a small change in any quantity.

Equivalent circuit

The equivalent circuit, illustrated in Fig.1(b), reveals how this loading effect occurs. The input resistance of the direct 1x probe connection is just the 1MΩ resistor within the scope, which we have called R1 in Fig.1(a). R1 and Rs actually form a voltage divider, so the scope sees only the voltage at D, which is the true voltage of the source reduced by the fraction (R1/(R1 + Rs)).

Typically, a digital multimeter has an input resistance of 10MΩ so using it has a less deleterious effect on the voltage. This is why the DMM reading is higher, at +4.9V.

You can calculate the value of the source resistance Rs in this case from these measurements and the definition given above. It works out to be about 200kΩ which is reasonable for this particular op amp circuit.

Let's define V as the unloaded output voltage of the source; ie, the potential at point D when neither the scope probe nor the DMM is connected to it. Using the voltage divider equa-

tion, the voltage V_p at D when only the 1x probe and scope is hooked on is:

$$V_p = V(R1/R1 + Rs)$$
$$= V(1M\Omega/1.2M\Omega)$$
$$= V/1.2$$

The scope reads V_p as +4.17V, so the unloaded output voltage at the point D is:

$$V = (1.2)(4.17) = 5V$$

The relatively low resistance of the scope input was the cause of the loading effect. It loaded the source and so caused the oscilloscope to read +4.17V instead of the true +5V.

Measurement rule-of-thumb

The cure for this loading effect is now obvious. The test instrument should have an input resistance much greater (preferably 100 times greater) than the output impedance of the source to be measured. A 100 times factor would limit loading errors to about 1%. But practical aspects like price, availability and frequency response will limit our selection of scope probes.

A common favourite, the 10x probe, as illustrated in Fig.2, is an excellent choice in most cases. This type of probe contains a 9MΩ resistor called Rp. Therefore the total probe connection resistance, Rin, is equal to Rp in series with the scope input resistance, R1. That is:

$$Rin = (Rp + R1)$$
$$= (9M\Omega + 1M\Omega) = 10M\Omega$$

If we substitute this 10x probe in the measurement shown in Fig.1, the oscilloscope would display a deflection of +4.9V, the same as the DMM reading, a satisfying result.

High voltage measurements

Fig.2 shows a second important use of the 10x probe. Here the source resistance is quite low (due to negative feedback) at the collector of transistor Q1 so loading is not a worry but the high voltages are! In this case we can use the fact that Rp (in the probe head) and R1 (in the oscilloscope) form a deliberate voltage divider. Any voltage which we apply to the probe tip will be reduced at the scope input terminal. The reduction fraction is:

$$V_{sc} = R1/(Rp + R1)$$
$$= 1M\Omega/(9M\Omega + 1M\Omega)$$
$$= 1/10.$$

That's why this probe is known as a 10x, because it produces a 10:1 voltage attenuation.

In the circuit of Fig.2, the high voltage of the supply (+450V) rules out use of the 1x probe and forbids direct connection to the scope's input. But the 10x probe is suitable, provided it has a voltage rating above 450V. This probe will reduce all waveform voltages to one tenth and the DC voltage at the scope input will be no more than +45V.

By dividing down the signal, the 10x probe effectively multiplies the V/div calibration on the attenuator switch by a factor of 10. So a 5V/div setting now means 50V/div and eight vertical divisions on the screen will correspond to a 400V range. Hence this 360V signal fits within the graticule limits.

Many top line scopes can sense when the 10x probe is connected to the modified BNC input terminals. Then internal logic circuits multiply the

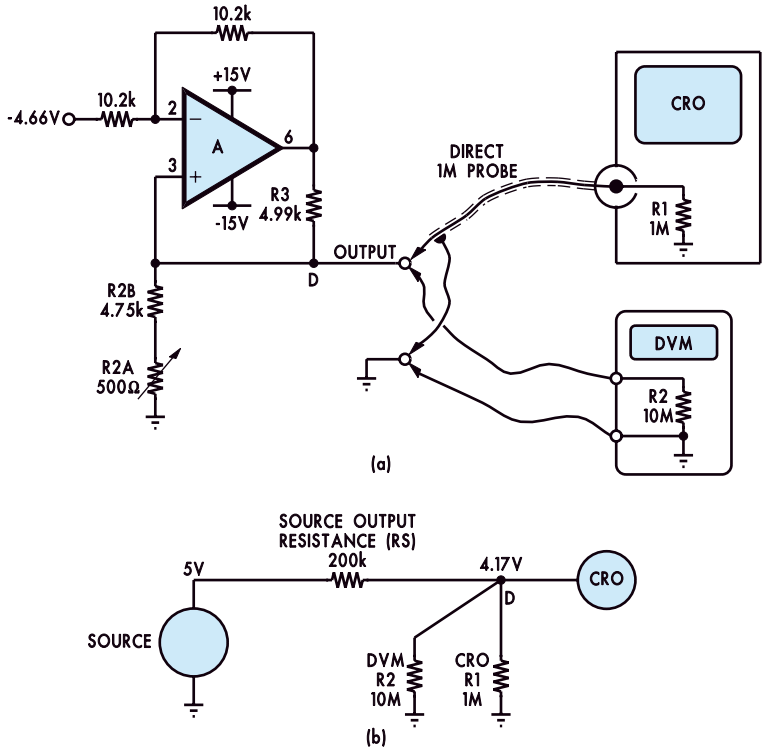


Fig.1: this dual phase amplifier (a) has a 5V output at point D where the source resistance is 200kΩ. But clipping the 1MΩ probe onto this point pulls the voltage down to 4.17V. The equivalent circuit (b) shows that the source resistance Rs forms an unwanted voltage divider with R1, the input resistance of the 1x probe and the scope. This reduces the voltage seen by the scope.

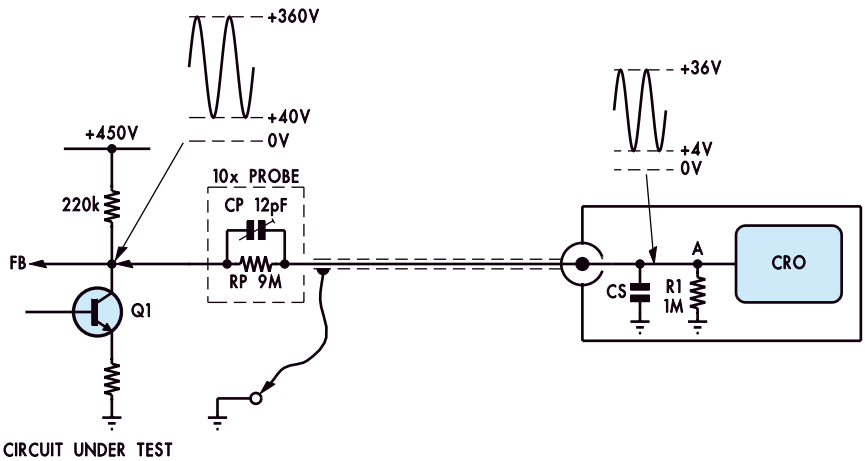


Fig.2: the 9MΩ probe resistor Rp and the 1MΩ scope input resistor R1, form a deliberate voltage divider. This reduces the voltage at the oscilloscope input terminal to one tenth of that at the probe tip.

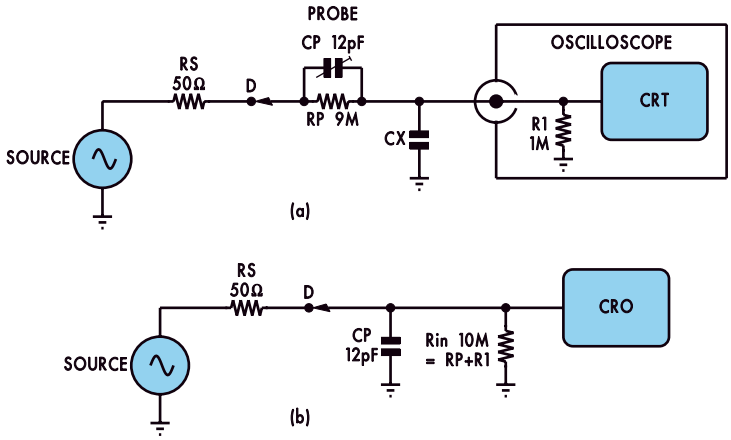


Fig.3: source (a) has output resistance Rs equal to 50Ω at point D. The high frequency equivalent circuit (b) shows that Cp forms an unwanted voltage divider with Rs. Cx represents the combined stray capacitance of the coaxial cable and the scope input.

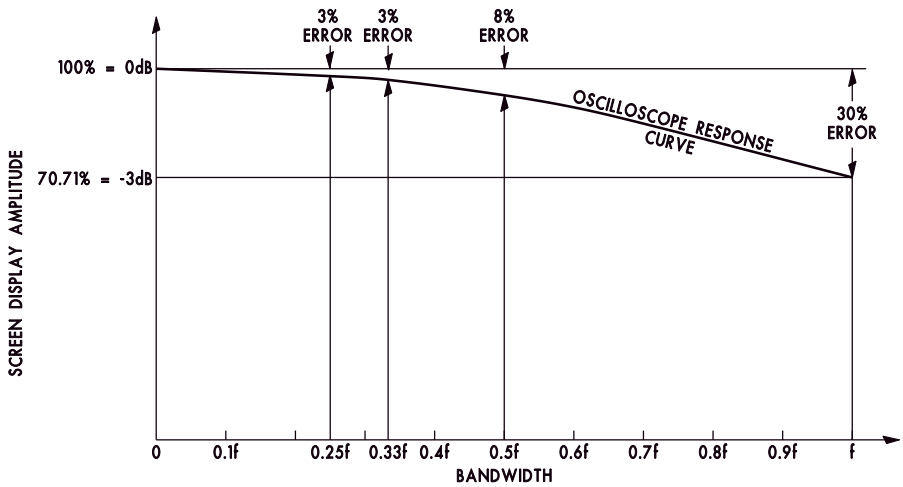


Fig.4: the amplitude response of an oscilloscope falls at high frequencies. At full rated bandwidth, the response is -3dB or 30% lower than it is at low frequencies.

on-screen readout by 10, to correctly display the voltage value at the probe tip. This facility is not provided in cheaper scopes and nor does it work when a scope is used with a probe of a different brand.

Safety precaution

Though the oscilloscope is safely working on reduced input voltages (because of the attenuation by the 10x probe) we must be aware that the probe tip still carries a lethal 360V! For safety we must keep the amplifier 0V line connected to the scope frame and to mains earth. And we never unplug the probe from the scope while the probe tip is still hooked onto a high voltage point.

All probes which contain only resistors and capacitors are called passive and oscilloscope manufacturers market a range of higher resistance units. A few of these are listed in Table 1 but not all probes on the market have voltage ratings as high as those shown here.

Direct 1x scope probes have only a small series resistance so they cause little attenuation of the signal being measured. They are useful for the display of very small voltages of low frequency signals, when measured at low impedance points, such as the outputs of op amps.

Some less common sources, like biological assay electrodes, have an extremely high output resistance. To display signals from these, active probes are required. Typically, these employ IGFETs and other active circuitry to provide an input impedance of 10GΩ and zero input capacitance.

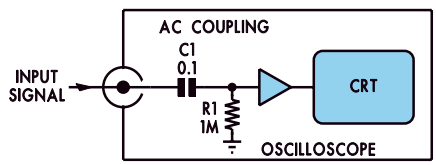


Fig.5: With AC (capacitive) coupling, the signal passes through a high pass filter. This will reduce the amplitude of low frequency signals and distort low frequency pulse waveforms.

Table 1

Probe Attenuation	R(in)	Maximum DC Voltage	Derated Above	Derated to
1x	1M	350V	-	-
10x	10M	600V	1MHz	30V @ 20MHz
100x	10M	1.5kV	200kHz	300V @ 20MHz
1000x	100M	20kV	100kHz	2kV @ 20MHz

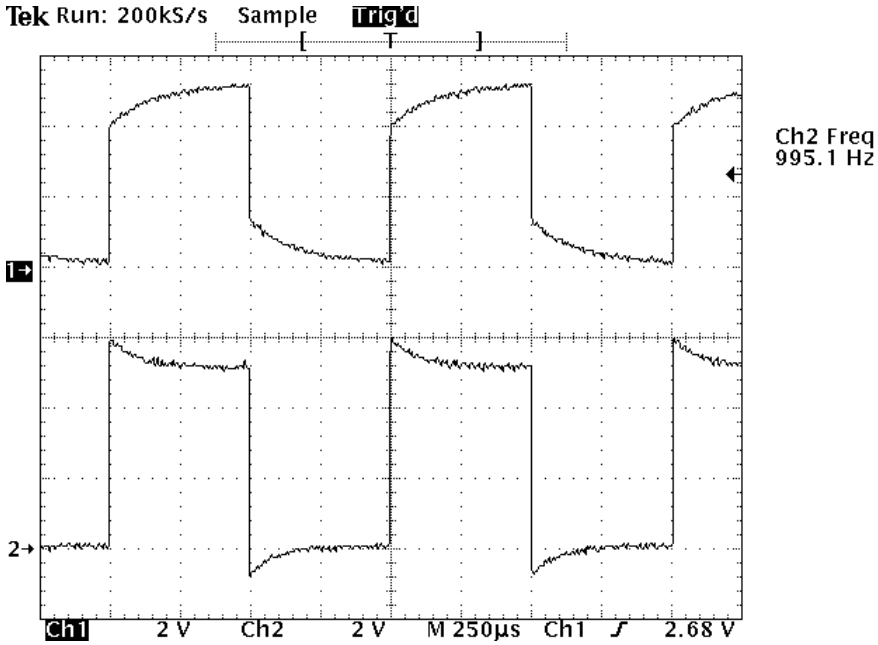
Oscilloscope bandwidth

Another scope parameter which new users often have difficulty coming to terms with is bandwidth. This could be easily measured if you had a synthesised RF signal generator with an output of 5V over a frequency range from 100kHz to 250MHz and an output impedance of just 50Ω.

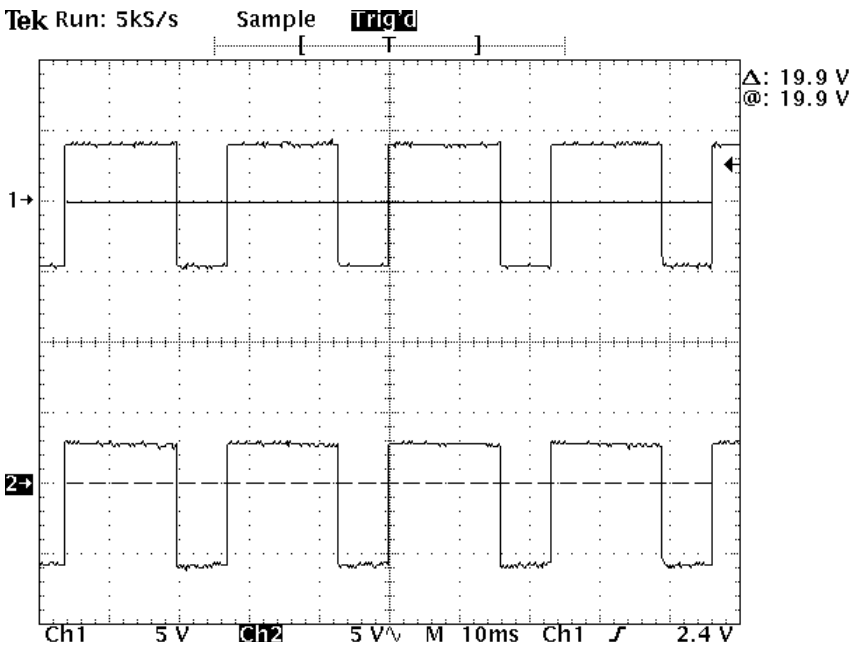
You might think that such a wideband source could easily demonstrate a scope's bandwidth. Would you just connect the 10x probe to the generator and then sweep over the frequency range? Fig.3 illustrates the setup, with the probe's internal resistance and capacitance shown.

However, you might be disappointed to find that, when the generator was set to the advertised bandwidth frequency of your high performance scope, say 250MHz, the vertical deflection is only half what it should be. So what does scope bandwidth mean?

The bandwidth of any oscilloscope is that high frequency at which the response has fallen to 70.7% (-3dB), compared to the reference frequency value, as illustrated in Fig.4. This



Taken from a Tektronix TDS360 digital oscilloscope, this screen printout shows the effects of incorrect adjustment of 10x probes on the scope's internal 1kHz compensation signal. Channel 1, the upper trace, shows too much probe capacitance (over-compensation) while the channel 2, lower trace, shows insufficient capacitance (under-compensation). The correct probe compensation adjustment would show a square wave with "square" corners.



This scope printout shows the effects of DC and AC coupling on a pulse waveform with uneven duty cycle. Channel 1, top trace, is DC coupled and it can be seen that the voltage swings equally above and below the zero reference line (solid horizontal cursor). Channel 2, lower trace, is AC coupled and the waveform has floated down with respect to the zero reference line (dotted horizontal cursor).

shows that the response of any oscilloscope is down by 30% at its advertised full bandwidth!

Furthermore, Fig.4 shows that the manufacturer's guarantee of an amplitude error of less than 2% only applies for signal frequencies less than one quarter of the rated bandwidth.

Table 2

Frequency	Capacitive Resistance
1MHz	13.3k
10MHz	1.3k
50MHz	265
100MHz	132
250MHz	53
300MHz	44
400MHz	33

Therefore, to make amplitude measurements with less than 2% error, we need a scope with a quoted bandwidth four or five times higher than the signal frequency. For example, accurate amplitude display of a 50MHz sinewave requires a 250MHz oscilloscope.

This is only part of the bandwidth story. As we noted above, testing an oscilloscope with a wideband generator could show an error of more than 50% at the advertised scope bandwidth. How could it get worse?

In most cases the advertised -3dB bandwidth of a scope applies only when signals are coupled directly into the instrument front terminal and not via a probe, because probes also have frequency limitations.

This is demonstrated by Fig.3(b), which is the high frequency equivalent of the circuit shown in Fig.3(a). As before, the resistance presented by the probe and scope connection is:

$$Rin = (Rp + R1) = 10M\Omega$$

where Rp is the resistance inside the probe and R1 is the input resistance of the oscilloscope.

In the equivalent circuit of Fig.3(b) we can ignore the 10MΩ input resistance Rin because it is so much higher than the 50Ω source resistance Rs. But we cannot discount the probe's input capacitance C_p which is equal to 12pF.

The capacitive reactance of C_p is:

$$Xc = 1/(2\pi fC_p).$$

This forms an unwanted voltage divider with the source resistance Rs. At high frequencies the resulting low value of Xc drastically reduces the signal amplitude before it enters the scope. Table 2 demonstrates the severity of this effect, with the reactance of 12pF at specific frequencies.

From Table 2, we observe that at 250MHz the probe's capacitive reactance has fallen to 53Ω. Now we will

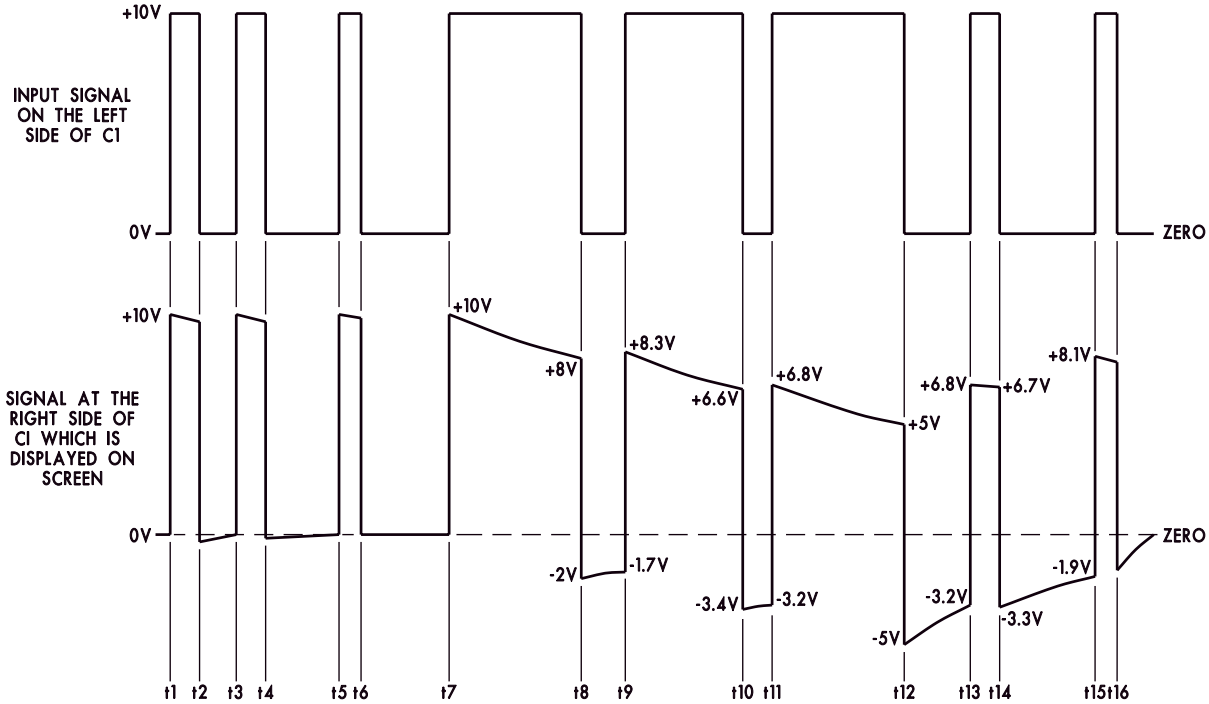


Fig.6: since a PWM signal has a varying duty cycle and therefore an effectively varying positive and negative DC offset, AC coupling will cause the waveform to waver above and below the 0V reference line.

see the reason why the amplitude displayed on the screen fell to 50%.

Firstly, looking at Fig.4(b), we see that at 250MHz the voltage divider effect of the 53Ω Xc with the 50Ω source resistance Rs reduces the signal voltage at D down to 70% of the unloaded source voltage (it's a vector calculation, because of the capacitor).

Secondly, as Fig.4 shows, the displayed amplitude will be further reduced to 70% of the voltage at the scope input, because the signal frequency is now equal to the 250MHz bandwidth of the scope. So the amplitude you would see on the screen will be reduced to (70% x 70%) = 50% of the unloaded source voltage. That explains why a high frequency measurement with a 10x probe can have such large errors.

Only in a few cases will a manufacturer guarantee that the advertised bandwidth applies at a specified probe tip. Examples include the Tektronix 400MHz oscilloscope model 2465B but only when used with their 1MΩ passive 10x probe model P6137.

Table 3 shows the input capacitance and bandwidth of typical probes.

Frequency pulling

Often, the application of a passive scope probe to some points of a circuit can have drastic effects, particularly in the case of crystal and other oscillators.

These require critical positive feedback gain and phase, set by specific small capacitor values, to maintain oscillation at the required frequency. But hooking a passive probe onto a high impedance point of these circuits can add 12pF of capacitance, upsetting the feedback. This action can either reduce the operating frequency or may stop oscillation altogether.

How do we avoid this? Many systems, including some TV receivers, contain buffered test points, where sensitive circuits are accessed either via an inbuilt resistor or a low impedance source follower.

Alternatively, a simple expedient is to attach a small resistor, about 10kΩ, to the probe and use the other end of that resistor as the probe point. The results may be inaccurate but at least you can monitor the waveforms. Another alternative is to use a high impedance active probe, such as listed in Table 3.

For frequencies above 500MHz, wideband active FET probes are available with a high input impedance and they require a separate supply. Examples include the Tektronix type P6204 which has a 1GHz bandwidth and the type P6217 which operates to 4GHz. Active probes accept small input voltages, typically below 10V.

For really wide bandwidth scopes, between 2GHz and 10GHz, low impedance divider probes are available, with input resistances of 50Ω, 500Ω or 5kΩ. They plug into the 50Ω input terminals on very high frequency oscilloscopes.

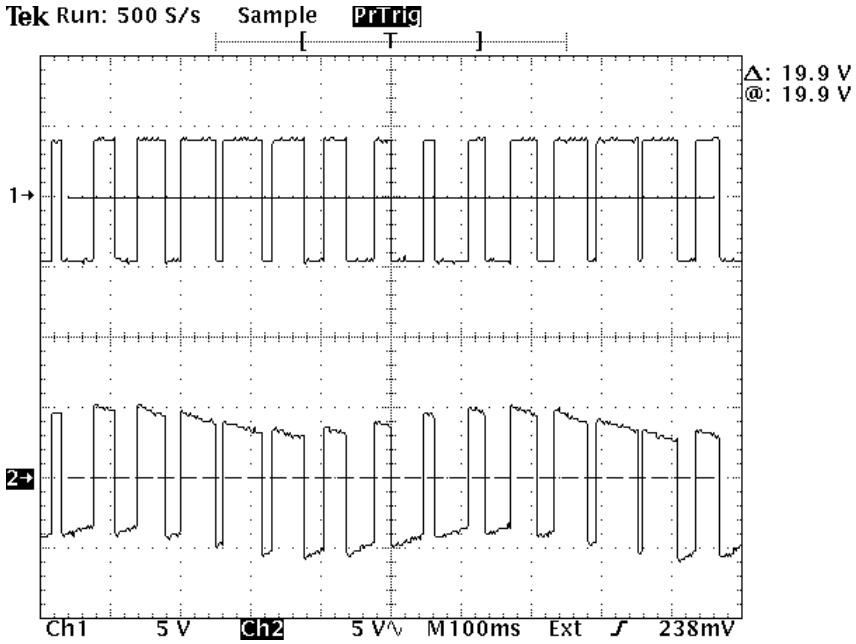
Table 3

Attenuation	R(in)	C(in)	Bandwidth
1x	1M passive	55pF	15MHz
10x	10M passive	12pF	100MHz
10x	10M passive	8pF	500MHz
100x	10M passive	2.7pF	250MHz
10x	100k active	0.4pF	4GHz
10x	500 divider	0.15pF	9GHz

Probe risetimes

Another area where a new oscilloscope can disappoint is when displaying square waves which are supposed to have fast rise and fall times. Fig.3(a) shows the connection as before and now we will explain why the probe capacitor Cp is there at all, in view of the trouble it causes when displaying very high frequencies.

The reason why Cp is inside the



This scope printout shows the effects of DC and AC coupling on a pulse waveform with varying pulse width (ie, pulse width modulation). Channel 1, top trace, is DC coupled while Channel 2, the lower trace, is AC coupled. The varying pulse width effectively becomes a varying DC offset which is reflected as a wavy modulation on the waveform, an erroneous display. This is the same effect as depicted in Fig.6.

probe becomes clear when you look at pulse risetimes. The probe's shielded cable and the oscilloscope's input stage add up to a considerable capacitance to ground, probably between 35pF and 100pF.

This we denote as Cx in Fig.3(a). If Cp did not exist in the probe head, then the probe resistor Rp, together with this stray capacitance Cx, would form a severe low pass filter. The effect would be a reduction in amplitude and a phase change in sinewave signals and a drastic slowing of the risetime of pulses as displayed on the screen.

Therefore the capacitor Cp has been deliberately included in the probe to correct these errors. But Cp must be correctly adjusted until the two time constants, RpCp and R1Cx, are equal.

To facilitate this adjustment, most oscilloscopes provide a fast-risetime 1kHz square wave calibrating signal from a terminal (usually) on the front panel. You just hook the probe onto this CAL terminal and adjust the probe capacitor Cp until the scope displays a true square wave.

If Cp is set too low, the square wave will be rounded off while if Cp is too high, the square wave will overshoot and undershoot. Naturally this Cp adjustment also has a big effect on the displayed bandwidth so if you don't adjust it correctly, it is yet another source of measurement error.

AC coupling

So far we have talked about large DC voltages and high frequencies but if you have a circuit with high DC voltages and small signals, you need to switch the scope's input to AC coupling. This enables you to use high input sensitivity while blocking out a large quiescent DC voltage. As Fig.5 illustrates, the signals then must pass through the R1C1 time-constant. This will reduce the amplitude of low frequency signals, distort square waves and pulses and can play merry hell with pulse width modulation (PWM) signals.

To see why, we need to critically look at just what it means to feed a signal through a coupling capacitor. In Fig.6 we have sketched a PWM signal which is applied to the left side of capacitor C1. Below that is the waveform which appears on the right hand side of C1 and is displayed on the oscilloscope screen.

At time t7, the input signal lifts the left side of C1 from zero to +10V, charging the capacitor. So the right side also rises to +10V. Between times t7 and t8, the input voltage remains steady. But the charge on C1 leaks away through the resistor R1, lowering the voltage on the right hand side of the capacitor from +10V to +8V. Then at time t8, the input voltage drops from +10V to zero.

Because this fall is abrupt, the potential on the right side of the capacitor must also fall by 10V; ie, from +8V to

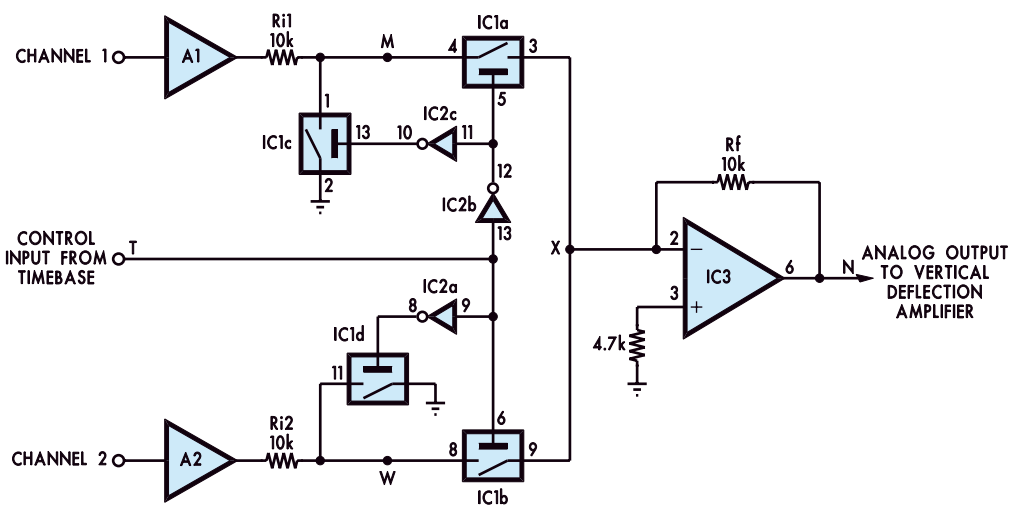


Fig.7: one possible circuit for the Chop/Alternate section of an analog scope. CMOS analog switches alternately switch the signals from channels 1 and 2 through to the vertical deflection amplifier.

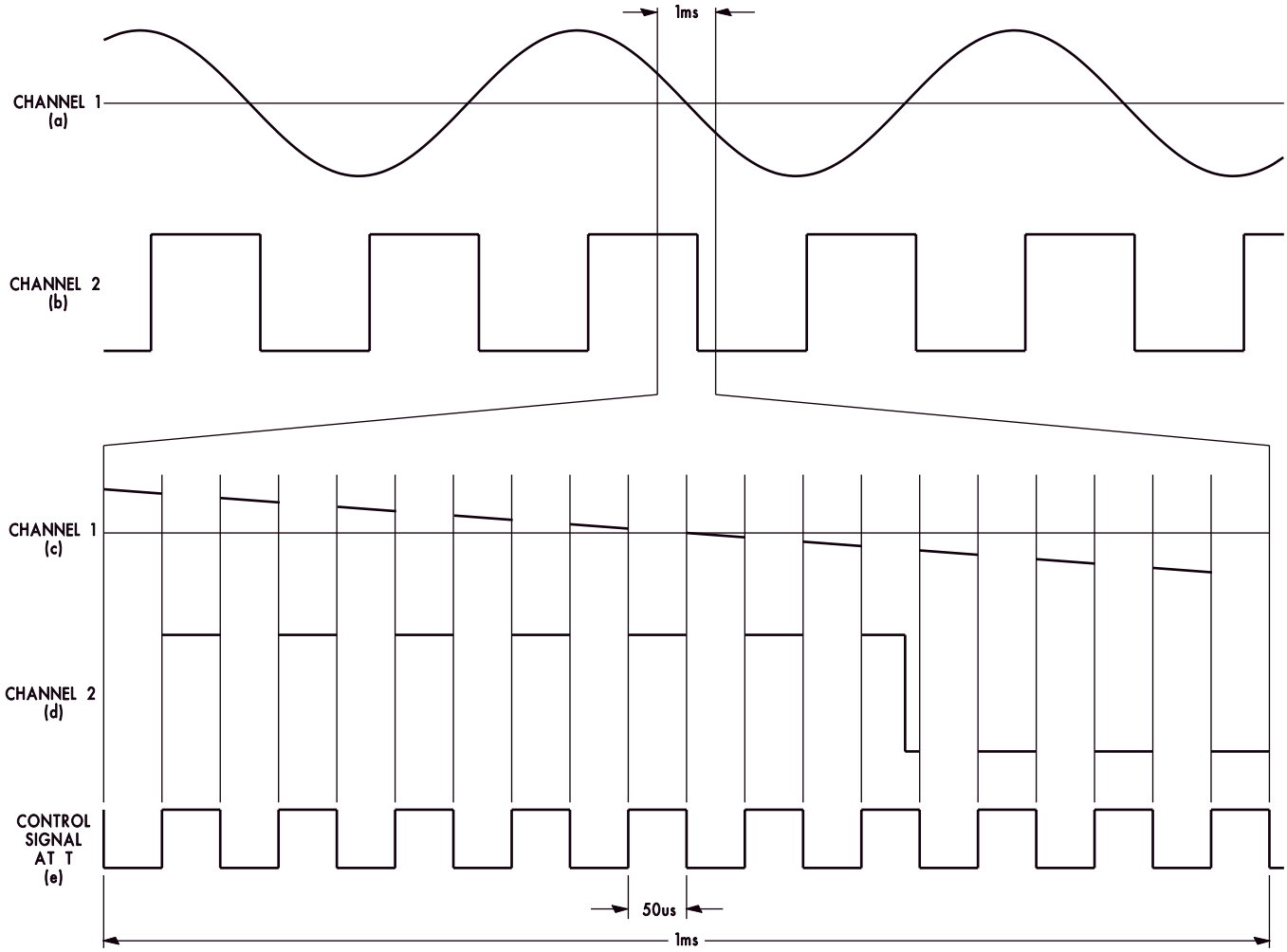


Fig.8: this series of waveforms illustrates how the Chop mode in an oscilloscope rapidly chops between the input channels to produce two waveforms on the screen. Waveforms (c), (d) and (e) show an expansion of the 1ms period in waveforms (a) and (b).

-2V, taking the displayed trace into negative regions. This may leak away to about -1.7V by time t9, when the input rises again. This time the +10V change in the input signal lifts the display up to +8.3V. During the long constant input between t9 and t10, the display again leaks down to +6.6V. You can see that the displayed waveform is far from the truth.

When the positive input pulses are long, with a duty cycle greater than 50%, the display progressively migrates downwards (duty cycle is the ratio of the pulse on-time to the pulse off-time). If the duty cycle remained constant, after many cycles the displayed signal would be displaced until the area enclosed between the positive regions of the waveform and the zero line is equal to the area enclosed between the negative regions and the zero line.

By this rule, the long duty cycle between times t7 and t12 will push the waveform downwards. But the same rule means that between times t13 and t16, when the duty cycle is short, the waveform display must rise above the zero line, in order to equalise positive and negative areas.

So the complex PWM waveform of Fig.6 will rise and fall as the duty cycle changes. The only cure is to monitor the waveform with DC coupling. AC coupling is a trap for young players – use it only when you must block high DC voltages.

Dual-trace operation

One of the really powerful benefits of a scope is the ability to monitor two signals at once but here again there are traps. If you want to measure the timing or phase differences between two signals you need to know just how your scope displays two different inputs on the screen simultaneously. What we are talking about is the choice between Alternate and Chop modes.

Fig.7(a) illustrates one possible circuit for the Chop/Alternate section of an analog scope. Two different signals on channels 1 and 2 firstly pass through their individual attenuators and preamplifier stages A1 and A2, then to the Chop/Alternate section which includes IC1, IC2 and IC3. You will easily follow its operation as we view it a bit at a time.

IC1a, b and d are CMOS analog switches and each turns on only when a logic high signal is applied to its control terminal. For example, IC1a conducts between pins 4 and 3 only when a logic high is applied to pin 5.

The timebase section of the oscilloscope, as well as providing the horizontal sweep, also feeds a control signal in at point T. This controls all four CMOS switches via inverters IC2a, IC2b and IC2c. IC3 is a summing operational amplifier, while Ri1 and

Ri2 are its two input resistors and Rf is the feedback resistor. Point X is the summing junction.

The gain from either channel 1 or channel 2 inputs to the output at point N is -(Rf/Ri) = -(10kΩ/10kΩ) = -1. Signals from point N feed to the vertical deflection amplifier for display on screen.

Now what happens when we select the Alternate display mode? Say we apply a signal to channel 1 input and a square wave to channel 2. If the timebase section feeds a low control signal to the point T, this will be inverted in IC2b and will present a logic high to pin 5 of gate IC1a, turning it on.

So the sinewave signal on channel 1 will feed through A1, through Ri1, IC1a and IC3, and will pass on to the vertical deflection amplifier, to be displayed on the screen. At the same time, gate IC1b is off, so channel 2 signals cannot pass to the vertical deflection amplifier.

But when a logic high signal is fed to point T, the conditions reverse. Analog switches IC1b and IC1c will conduct and IC1a turn off, allowing the channel 2 signal to be displayed on the screen. The control signal at point T is high on the 1st, 3rd, 5th, 7th, etc sweeps and low on the 2nd, 4th, 6th, 8th, etc. Thus, all odd sweeps display the sinewave on channel 1 and all even sweeps show the square wave on channel 2.

You can use the individual vertical position (shift) controls to move the two displays apart. At slow sweep speeds, the display alternates between signal 1 in the upper half of the screen and signal 2 in the lower screen.

At fast sweep speeds, the persistence of the screen phosphor enables you to see both signals continually on the screen. Hence, Alternate mode is successful with fast sweep speeds but unsuitable at slow sweeps.

Chop mode

Now what happens if you change to "Chop" mode. This causes a separate high frequency oscillator within the timebase unit to toggle the control signal fed to point T (toggle means to switch continually between logic high and low). This is done at a fixed fast rate, perhaps 10kHz, as illustrated in Fig.8 but in some high frequency oscilloscopes the toggle rate may be as high as 1MHz.

In the example shown in Fig.8, the main sweep is switched to 100 milliseconds per division, which takes one second for each full sweep. The sinewave on channel 1 has a frequency of about 3.5Hz and the square wave on channel 2 is about 6Hz. The control signal at point T has period equal to 1/10kHz = 100µs as Fig.8 shows.

This makes channel 1 conduct through IC1a for 50µs, channel 2 conducts through IC1b for the next 50µs and so on. Both input signals are thus chopped up into thousands of little time segments 50µs long, like two lines of ants crawling across a page.

On the screen are displayed these 20,000 discontinuous segments of the input signals, as IC1a and IC1b conduct in turn. A small sector of both traces is shown in Fig.8(d) & (e) drawn one thousand times time-expanded.

While T is at logic high, a small segment of the sinewave (a) is displayed in the upper half of the screen. But when T is at logic low, a short piece of the square wave (b) appears on the lower half at (e). While one signal is displayed, the other is blanked off. This process continues repeatedly, right across the screen. The slight blurring due to the width of the light spot makes each trace appear continuous.

If we raised the sweep speed sufficiently we would see the discontinuous nature of the display. So chop mode is unsuitable for very fast sweep speeds. In some scopes Chop mode is automatically selected at slow timebase speeds and Alternate is selected at high sweep speeds.

Now we can see why Chop and Alternate modes can affect timing and phase comparisons between two different signals. Alternate mode leads to impossibly wrong results, because it allows the oscilloscope to trigger independently on each channel; time correlation is completely lost. Therefore, Chop mode must be used when comparing the timing of different signals.

Phase shift

A final vital point to note here is the phase shift which AC coupling produces, as noted above. Therefore, when comparing phases and timing of different signals, switch both channels to DC coupling or switch both channels to AC coupling. Don't have channel 1 AC-coupled and channel 2 DC-coupled; that will lead to serious errors. **SC**

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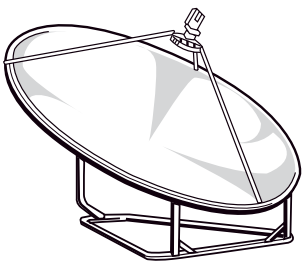

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RADIO CONTROL

BY BOB YOUNG

Multi-channel radio control transmitter; Pt.7

This month, we deal with the final system alignment and the programming instructions for the Mk.22 transmitter. This is mainly a matter of deciding the features you want and connecting the various wander leads.

To begin it will be necessary to re-read the May, June and July 1996 issues of SILICON CHIP in which the basic instructions for the alignment of the RF module and the encoder are discussed. As we left the project in the July issue, the transmitter was completely assembled and working up to the point of radiating a modulated signal albeit not correctly tuned.

Before we go any further, make sure your batteries are fully charged before you start. Charging is accomplished using a power supply set at 60mA or a dedicated plugpack charger. These are available at any good model shop however you will need to change the connectors.

The charge plug must be a non-shorting 2.5mm jack type and is inserted into the socket located on the lower front right of the Tx. The tip of the charge plug is wired positive. Remove all micro-shunts and leads from the encoder and RF modules.

It is probably best to begin proceedings with the adjustment of the expanded scale voltmeter circuitry as this will give a good indication of the state of your batteries during the alignment process. Trimpots VR16 and VR17 on the encoder PC board control the set points and range of the meter. VR17 sets the low point (+8.8V) and VR16 controls the range (sensitivity).

To adjust the meter, hook up a variable voltage source to the encoder GND and +9.8V pins on TB7. Set both trimpots to their midpoints, set the power supply to +8.8V and switch on power. Set the meter pointer to "0" using VR17. Now increase the voltage to +10.8V and set the pointer to "10" using VR16. Drop the volts back to +8.8V and reset VR17. Continue this cycle until the meter reads "10" at +10.8V and "0" at +8.8V.

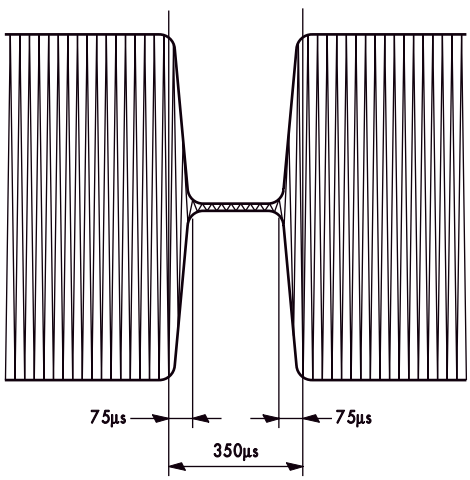


Fig.1: the ideal modulated waveform and recommended rise times.

With this setting, the meter will peg immediately after charging and drop back very quickly to less than "10" as the surface charge is dissipated. As nicads are considered exhausted at 1.1V per cell, the meter will give an excellent indication of the state of charge of your batteries. Stop flying at "0" as you will have only about 10-15 minutes of safe flying after this.

Slip the Tx power input socket back onto TB7 (PWR) and fire up your spectrum analyser (yes, as I have stated before, you will need an analyser) and plug in the power connector to the RF module.

Open the May 1996 issue of SILICON CHIP and work your way through the tuning sequence presented in that issue. The production antenna ended up at 1.3 metres instead of 1.5 metres long but the tuning range will accommodate that change.

The only area needing special attention is the final shape of the modulated waveform. Fig.1 shows the ideal waveform and recommended rise

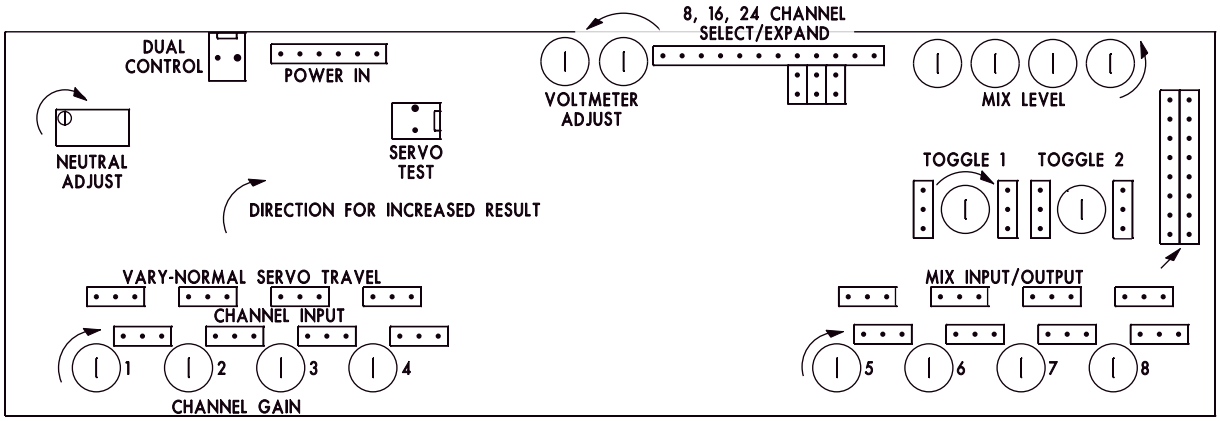


Fig.2: an overview of the encoder layout showing the major programming controls and plug groups. Notice that all eight input configurations are identical.

times. It may be necessary to play with the value of R7 on the RF module, as mentioned previously, to adjust for the spread in the FETs.

Once the RF module is properly tuned, seal the ferrite slugs with wax to prevent them moving. It is now possible to drive a receiver from the transmitter. As all input stages have been disabled, only the default waveform will be transmitted (all 1.5ms pulses). Switch on the receiver and plug a servo set to 1.5ms neutral (most modern servos) into channel 1.

Better still, plug in a pulse width meter. Remove all leads and micro-shunts from the encoder PC board, switch on the transmitter and the pulse width meter should read 1.5ms or the servo move to neutral, if you have followed the instructions in the June 1996 issue.

The 10kΩ 10-turn trimpot VR2 (NEUT) is there to provide neutral adjustment. Clockwise rotation increases the pulse width. Use this to set the neutral if it is not already correct and switch the Tx OFF. Try to get into the habit of changing the plugs and sockets with the Tx OFF. There are only one or two plugs that may cause problems and these are not usually moved once in place (power sockets). The Tx must be switched OFF when changing the RF module.

The Mk.22 transmitter is now ready for business, so let us move on to the real work.

Programming the encoder

The Mk.22 encoder utilises what is perhaps best defined as "Wander Lead" programming. All controls are wired with identical 3-pin sockets (see Fig.2, page 80, July 1996 issue) which are free to wander anywhere on the PC board. All control elements are wired in an identical fashion with the centre lead carrying the signal and the two outside leads for positive and negative. All control inputs on the encoder are fitted with identical, mating 3-pin headers (plugs). Any control may be connected to any channel in any order.

This arrangement results in a transmitter of the utmost flexibility. Even the front panel controls can be programmed in the most suitable manner for the task at hand. Toggle switches can become retract switches, dual rate switches or mix IN-OUT switches. Sense of operation may be reversed, channel allocation changed or direction of the servo travel reversed very quickly and without complex menu stepping.

Fig.2 gives an overview of the encoder layout showing the major programming controls and plug groups. Notice that all eight input configurations are identical so that it is only necessary to master one to have complete mastery over all eight or indeed 24 channels.

Each channel input has three main components: the VARY-NORMAL 3-pin header set, the CHANNEL INPUT 3-pin header set and an Adjustable Servo Travel Volume (ATV) potentiometer – see Fig.3. Each of the channel input sets are numbered on the PC board and run from left to right. These three items give rise to an almost limitless variety of programming options.

We will work through some of these options, paying particular attention to the basic principles involved, in order to build a good knowledge of how the system works. This will make the more complex programming tasks (such as CROW) much easier to understand when we describe them in coming issues.

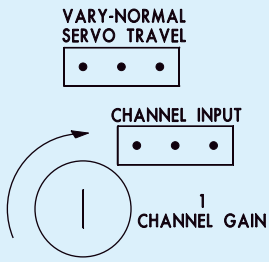


Fig.3: each channel input has three main components: the VARY-NORMAL 3-pin header set, the CHANNEL INPUT 3-pin header set and an Adjustable Servo Travel Volume (ATV) potentiometer.

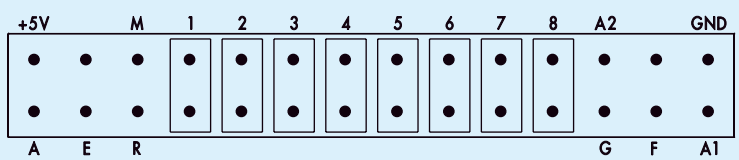


Fig.4: this diagram shows how the various micro-shunts (shorting links) must be placed across TB10, if the configuration module is not used.

We will begin with the simplest and most fundamental tasks and work forward from there. Load the appropriate micro-shunts and sockets as we go through the programming sequence.

Configuration module

The configuration module is not used in the basic Mk.22 transmitter. This was briefly mentioned and pictured in the June 1996 issue. If the module is not plugged into the configuration port TB10, then micro-shunts (shorting links) must be placed across TB10 as shown in Fig.4 to complete these open circuit input leads (see circuit in the March 1996 issue). These micro-shunts also play an important role in the mixing programming and we will deal with that later.

Channel allocation

As a result of the wander lead concept, channel allocation is a matter of deciding which controls should utilise which channel and plugging the 3-pin sockets onto the appropriate CHANNEL INPUT header pins. Channel allocation is a most important function when we come to such complex programming options as CROW, changing stick modes or matching a Mk.22 Tx to another brand of radio. As glitches tend to affect channel 1 more than any other channel, it is best to keep the flying controls away from channel 1.

The standard Silvertone channel allocation is as follows:

Channel	Allocation
1	motor
2	aileron
3	elevator
4	rudder
5	gear
6	flaps
7	aux 1
8	aux 2

Other brands of R/C equipment use different channel allocations. To match a Mk.22 Tx to a model already fitted with another brand of receiver, it is a simple matter to duplicate the channel allocation by rearranging the order of the sockets.

Servo reversing

Servo reversing is simply a matter of rotating the 3-pin socket on any of the CONTROL INPUT headers by 180°. Keep in mind that any error from absolute neutral will be doubled. For example, if the throttle servo is at one end before reversing, then it will immediately fly to the other end when reversed. If the trim is at absolute neutral when the socket is reversed, then no servo movement will be apparent.

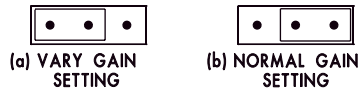


Fig.5: the sense of operation on the toggle switch for dual rate operation can be reversed by reversing the 3-pin socket on the VARY-NORMAL header.

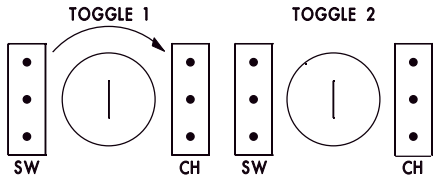


Fig.6: use this diagram when programming toggle switch operation.

Programming servo travel

In order to simplify the programming, certain configurations call for the ATV (adjustable servo travel volume) potentiometer to be connected to become a completely different type of volume control. The VARY-NORMAL header pin sets provide this function. When a micro-shunt is placed on the centre/left pair of pins as in Fig.5(a), the CHANNEL GAIN potentiometer is programmed as the ATV potentiometer. In this mode, servo travel may be adjusted from 20-120% (0.9 - 2.1ms) of the normal servo travel using the channel gain (ATV) potentiometer. Clockwise rotation increases the amount of servo travel.

If the micro-shunt is placed on the centre/right pair of header pins, as in Fig.5(b), then the ATV pot is allocated to other functions and the servo travel reverts to the NORMAL non-adjustable 100% level (1 - 2ms) and the ATV potentiometer is no longer available for servo travel adjustment.

At this point the transmitter should have all of the micro-shunts loaded on TB10, the main controls hooked to the CHANNEL INPUT headers and the micro-shunts loaded on the VARY-NORMAL headers. You can now move multiple servos simultaneously. This completes the basic programming and we will now move on to some of the more advanced features.

End point adjustment

Adjusting throttle linkages can be a tricky business as it is often almost impossible to get both ends exactly right. Using the ATV in conjunction with adjustable linkages overcomes this problem. Whilst not a true end point adjustment it certainly will adjust both end points simultaneously and will set the exact amount of servo travel needed to match the carburettor arm travel.

Dual rate programming

All 24 channels may be programmed for DUAL RATE operation. Simply remove the micro-shunt from the VARY-NORMAL headers on the channels intended for DUAL RATE operation and connect the desired toggle switches to the appropriate headers. Any of the front panel toggles can be used on any channel. The choice should be based on convenience of operation.

Sense of operation of the toggle switch can again be reversed by simply reversing the 3-pin socket on the VARY-NORMAL header – see Fig.5. When the toggle is in the VARY position the ATV potentiometer becomes the DUAL RATE set pot. Thus with the switch in the NORMAL location, the ATV pot is disabled and a non-adjustable 100% servo travel is available. With the switch in the VARY position, the ATV pot is used to set the amount of DUAL RATE variation. It is usual to select the VARY position with the toggle DOWN.

The amount of DUAL RATE adjustment ranges from 20% to 120%. Anticlockwise rotation decreases the amount of servo travel. Note that it is possible to program the Mk.22 Tx for increased throw in the DUAL RATE setting.

Toggle switch programming

There are two identical toggle switch modules built into the main encoder PC board module. These are located on the righthand side of the PC board just above the righthand input groups (see Fig.2) These modules consist of two 3-pin headers and a potentiometer.

Fig.6 shows these in detail. Note that the lefthand 3-pin header of each toggle module is labelled SW and this

Kit Availability

Kits for the Mk.22 transmitter are available in several different forms, as follows:

Fully assembled transmitter module	$125.00
Basic transmitter kit (less crystal)	$89.00
Transmitter PC board	$29.50
Crystal (29MHz)	$8.50
Fully assembled encoder module	$159.00
Encoder kit	$110.00
Encoder PC board	$29.50
Transmitter case kit	$395.00
Full transmitter kit (includes all the above)	$594.00

Post and packing of the above kits is $3.00. Payment may be made by Bankcard, cheque or money order to Silvertone Electronics, PO Box 580, Riverwood, NSW 2210. Phone (02) 533 3517.

will receive the 3-pin socket from the toggle switch (see Fig.2c, July 1996 issue). Thus, any toggle switch on the Tx front panel may be used as the actuator for the toggle channels.

The righthand 3-pin header labelled CH is the output connection. The short jumper cable with a 3-pin socket at each end (see Fig.2e, July 1996 issue) is connected to this header. The other end of this patch cord can go to any CHANNEL INPUT header in your channel allocation plan. Thus any two channels may be allocated to toggle switch actuation.

Servo reversing is available simply by reversing the CHANNEL INPUT socket as normal. A novel feature is the ability to very quickly reverse the sense of operation of the toggle switch by simply reversing the socket on the SW header. Thus UP-ON becomes DOWN-ON.

With the channel input programmed for NORMAL mode, adjusting the toggle module potentiometer will provide from almost zero to 100% travel volume. Clockwise increases the servo travel.

Another novel feature of this arrangement is that 180° of servo travel is easily obtained by using the toggle module potentiometer in conjunction with the VARY mode ATV pot. Some care is needed here in case the brand of servo you are using has its rotation angle limited by internal stops to less than 180°. Check to ensure that the servo is not straining against the internal end stops.

There is provision for two toggle modules on the standard encoder PC board.

Programming knob control

The standard Mk.22 case is punched for four toggle switches and two knob controls. The knob control consists of a panel-mount potentiometer upon which are mounted limiting resistors and a cable fitted with a 3-pin socket (see Fig.2d, July 1996). The resistors allow the full 270° of rotation to be used without driving the channel beyond the electronic limits allowable.

Thus, the knob control is a completely self-contained proportional control element which may be treated as one axis of a 2-axis stick assembly. It may be allocated and reversed in the normal manner.

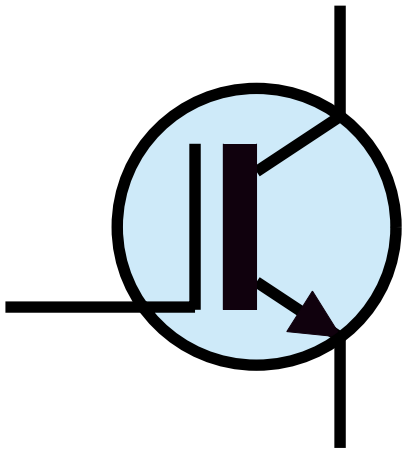
There are two knob controls in the standard Mk.22 transmitter, however all eight channels could easily be knob controls in a suitable case.

Programming slide control

A slide control unit is available as an option and again may be considered a single axis proportional control element. It may be allocated and reversed as normal. However, this would require a slot to be cut in the case by hand. A slide control suitable for flaps is available as an optional extra.

That is all that space allows for this month. Next month we will discuss mixing, dual control and frequency interlock. **SC**

Scan Audio Pty Ltd



An introduction to IGBTs

When it comes to high power switching applications circuit designers generally choose between bipolar transistors or Mosfets. But there is an alternative which combines the best of both devices – the insulated gate bipolar transistor or IGBT. It can be thought as a bipolar transistor with a high impedance gate instead of a low impedance base.

More and more we are seeing heavy duty switch-mode power circuits – inverters, power supplies, induction motor control and so on. As the applications continue to become more stringent, semiconductor manufacturers need to create products that approach the ideal switch. The ideal switch would have: (1) zero resistance or forward voltage drop in the on-state; (2) infinite resistance in the off-state; (3) switch on and off with infinite speed; and (4) would not require any input power to make it switch.

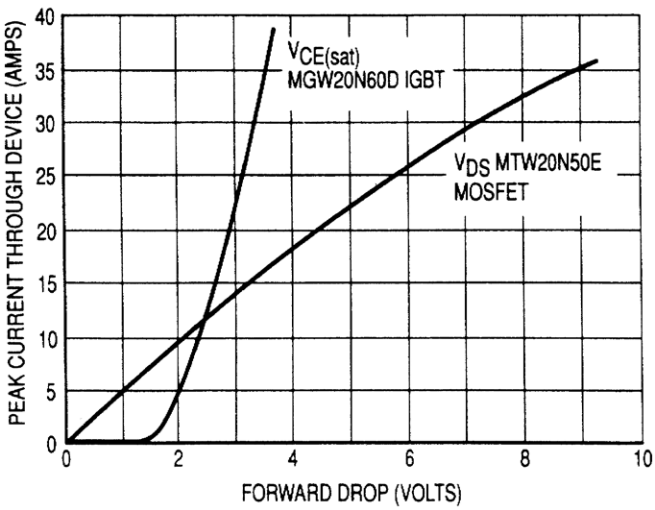


Fig.1: reduced forward voltage drop of an IGBT compared to a Mosfet with similar ratings.

Since we don't yet have the ideal switch, designers must choose a device that best suits the application. The choice involves considerations such as voltage, current, switching speed, drive circuitry, load and temperature effects. There are a variety of solid state switch types available and they all have their strong and weak points.

High voltage power Mosfets

The characteristics that are most desirable in a solid-state switch are fast switching speed, simple drive requirements and low conduction loss.

For low voltage applications, power Mosfets offer very low on-resistance [$R_{DS}(on)$] and approach the desired ideal switch. But in high voltage applications, Mosfets exhibit increased $R_{DS}(on)$ which results in increased conduction losses. In a power Mosfet, the on-resistance is proportional to the breakdown voltage raised to approximately 2.7:

$R_{DS(on)} = (V_{DS})^{2.7}$

Mosfet technology has now advanced to a point where $R_{DS(on)}$ is near the theoretical limit. A new approach is needed to obtain very low on-resistance without sacrificing switching speed. This is where the IGBT comes in.

By combining the low conduction loss of a BJT (bipolar junction transistor) with the switching speed of a power Mosfet an optimal solid state switch would be obtained. In fact, the IGBT is a spin-off from power Mosfet technology and its structure closely resembles

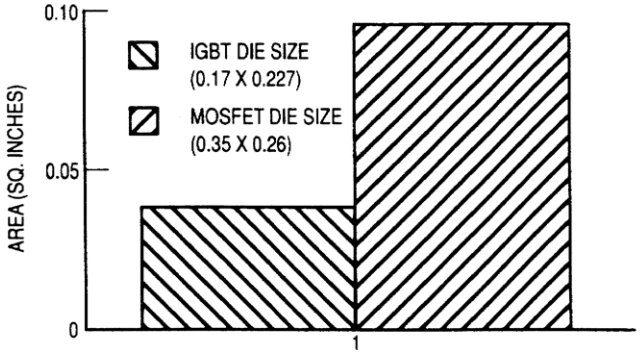


Fig.2: reduced die size of an IGBT compared to a Mosfet with similar ratings.

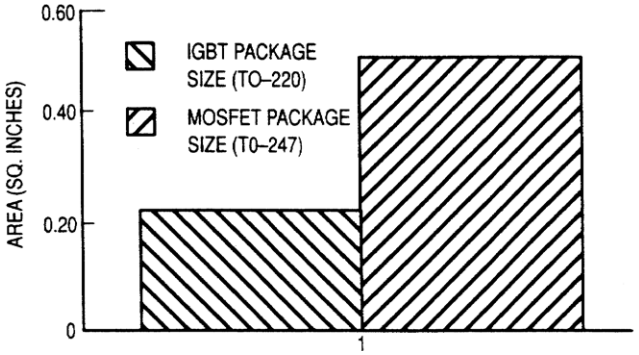


Fig.3: reduced package size of an IGBT compared to a Mosfet with similar ratings.

that of a power Mosfet. The IGBT has a high input impedance and fast turn-on like a Mosfet. And they have an on-voltage and current density comparable to a bipolar transistor.

Speaking IGBT

Before we go any further, perhaps we should tell you how to say IGBT. Instead of referring to them as "Iggbets" most designers call them by the initials, "eye gee bee tees" – more of a mouthful perhaps but that's the way it is.

IGBTs are replacing Mosfets in high voltage applications where conduction losses must be kept low. In fact, SILICON CHIP featured a 2kW sinewave inverter with IGBTs in the October 1992 to February 1993 issues. Four 1kV IGBTs were used in the high voltage H-pack section where 365V DC is converted to a 50Hz sinewave using pulse width modulation at around 4kHz. In this instance, we were forced to use IGBTs because no combination of currently available power Mosfets was sufficiently rugged for the job.

With zero current switching or resonant switching techniques, IGBTs can be operated in the hundreds of kilohertz range. Typically though, although turn-on speeds are very fast, turn-off of the IGBT is slower than a Mosfet. It exhibits a significant current fall time or "tailing". This tailing restricts IGBTs to operating at less than 50kHz in traditional "square wave" PWM switching applications.

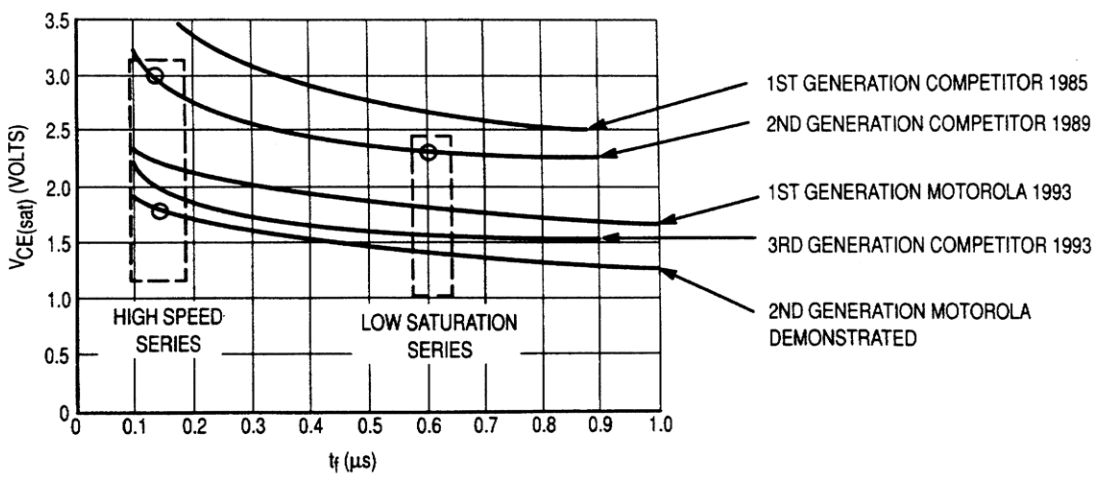
Up to 50kHz then, IGBTs are often a better solution than bipolar transistors, Mosfets or thyristors (SCRs). Compared to SCRs, the IGBT is faster, has better dv/dt immunity and above all, has better gate turn-off capability. While GTOs (gate turn-off SCRs) are capable of being turned off at the gate, substantial reverse gate current is required, whereas turning off an IGBT only requires the gate capacitance to be discharged. Against that, SCRs have a slightly lower forward voltage and a higher surge current capability than IGBTs.

Many of today's switching circuits use Mosfets because of their simple gate drive. Since the structure of both devices is similar, the change to IGBTs can be made without having to redesign the gate drive circuit. Like Mosfets, IGBTs are transconductance devices and can remain fully on if the gate voltage is held above a certain threshold.

As shown in Fig.1, using an IGBT in place of a power Mosfet dramatically reduces the forward voltage drop at currents above 12 amps. By reducing the forward drop, the conduction loss is decreased. The gradual rising slope of the Mosfet in Fig.1 can be attributed to the relationship of V_{DS} to $R_{DS}(on)$. The IGBT curve has an offset due to an internal forward biased p-n junction and a fast rising slope typical of a minority carrier device.

Replacing a Mosfet with an IGBT can improve the efficiency and/or reduce the cost. As shown in Fig.2, an IGBT has considerably less silicon area than a similarly rated Mosfet. The reduced silicon area makes the IGBT the lower cost solution. Fig.3 shows the package area reduction by using an IGBT. This suits it for designs where space is restricted.

Fig.4: forward voltage drop ($V_{CE(sat)}$) and fall time (t_f) has improved since IGBTs were introduced.



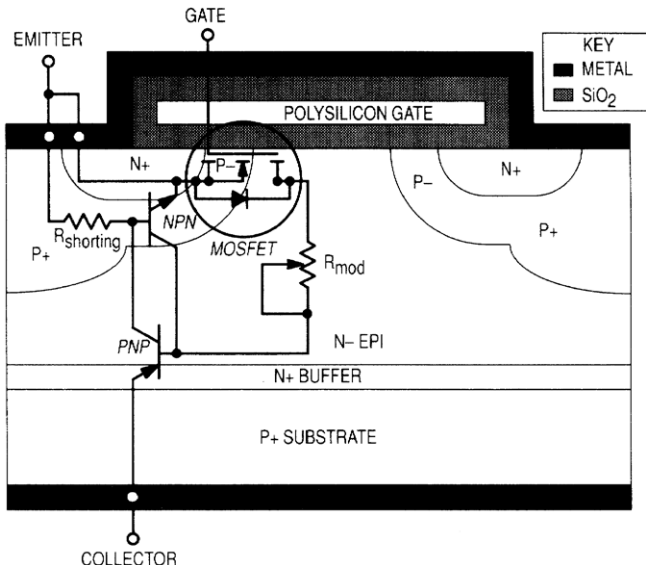


Fig.5: cross-section and equivalent schematic of an insulated gate bipolar transistor (IGBT) cell.

When compared to BJTs, IGBTs have similar ratings in terms of voltage and current but the isolated gate in an IGBT makes it simpler to drive. BJTs used as switches require sufficient base current to maintain saturation. Typically, the base current needs to be at least 1/10th of the collector current. BJT drive circuits must therefore be sensitive to variable load conditions.

In other words, base current for a BJT must be kept proportional to the collector current; otherwise the device will come out of saturation with high-current loads and will have excessive base drive under low-load conditions. Either way, it can lead to increased power dissipation.

BJTs are minority carrier devices and charge storage effects including recombination slow the performance when compared to majority carrier devices such as Mosfets. IGBTs also experience recombination that accounts for the current "tailing", yet IGBTs have been observed to switch faster than BJTs.

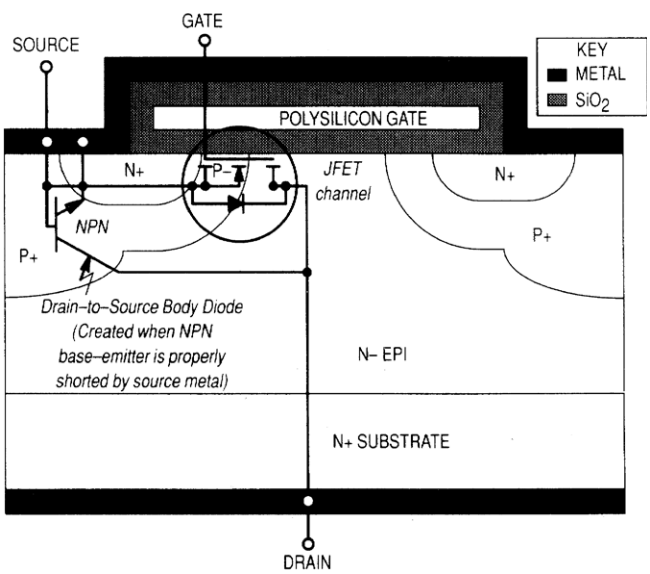


Fig.6: cross-section and equivalent schematic of a metal-oxide-semiconductor field-effect transistor (Mosfet) cell.

Since the introduction of IGBTs in the early 1980s, semiconductor manufacturers have learned how to make the devices faster. As illustrated in Fig.4, some trade-offs in conduction loss versus switching speed exist. Lower frequency applications can tolerate slower switching devices. Because the loss period is a small percentage of the total on-time, slower switching is traded for lower conduction loss. In a higher frequency application, just the opposite would be true and the device would be made faster and have greater conduction losses.

Notice that the curves in Fig.4 show reductions in both the forward drop $V_{CE(sat)}$ and the fall time t_f of newer generation devices. These capabilities suit the IGBT for applications such as motor control, power supplies and inverters which require devices rated at 600-1200V.

IGBT structure

The structure of an IGBT is similar to that of a double diffused (DMOS) power Mosfet. One difference between a Mosfet and an IGBT is the substrate of the starting material. By varying the starting material and altering certain process steps, an IGBT may be produced from a power Mosfet mask; however, at Motorola, mask sets are designed specifically for IGBTs. In a Mosfet the substance is P+ as shown in Fig.5.

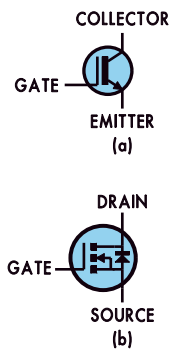


Fig.7: the symbols for IGBTs (a) and Mosfets (b).

The n- epi resistivity determines the breakdown voltage of a Mosfet as mentioned earlier using the relationship: $R_{DS(on)} = (V_{DS})^{2.7}$

To increase the breakdown voltage of the Mosfet, the n- epi region thickness (vertical direction in the diagram) is increased. Reducing the $R_{DS(on)}$ of a high voltage device requires a greater silicon area to make up for the increased n- epi region.

The effects of the high resistive n-epi region were overcome by conductivity modulation. The n-epi was placed on the P+ substrate, forming a pn junction where conductivity modulation takes place. Because of conductivity modulation, the IGBT has a much greater current density than a power Mosfet and the forward voltage drop is reduced. Now the P+ substrate, n-epi layer and P+ "emitter" form a BJT transistor and the n-epi acts as a wide base region.

Current tailing has been mentioned above. The device structure shown in Fig.5 provides an insight into tailing. Minority carriers build up to form the basis for conductivity modulation. When the IGBT turns off, these carriers do not have a current path to exit the device. Recombination is the only way to eliminate the stored charge resulting from the build-up of excess carriers. Additional recombination centres are formed

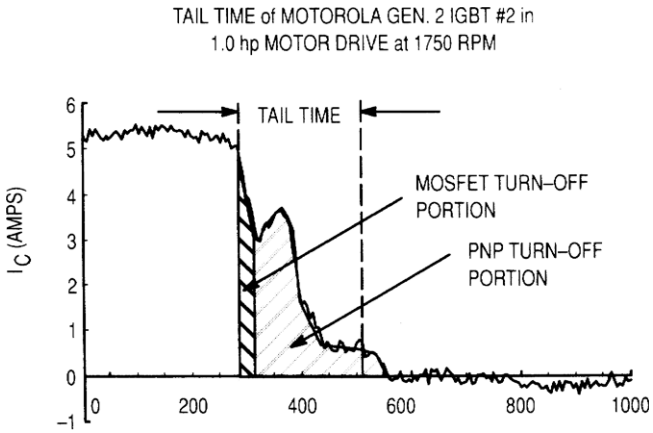


Fig.8: IGBT current turn-off waveform.

by placing an N+ buffer layer between the n-epi and P+ substrate.

While the N+ buffer layer may speed up recombination, it also increases the forward voltage drop. Hence the tradeoff between switching speed and conduction loss becomes a factor in optimising performance. The N+ buffer layer also prevents thermal runaway and punch-through of the depletion region. This allows a thinner n- epi to be used which somewhat decreases forward voltage drop.

Four layers

The IGBT has a four layer (PNPN) structure, resembling that of an SCR. But unlike the SCR where the device latches on and gate control is lost, an IGBT is designed so that it does not latch on. Full gate control is available at all times.

Because the IGBT is a four-layer structure, it does not have the inverse parallel diode inherent in power Mosfets. This is a disadvantage to motor control designers who use the anti-parallel diode to recover energy from the motor.

Like a Mosfet, the gate of an IGBT is electrically isolated from the rest of the chip by a thin layer of silicon dioxide, SiO_2. This gives it a high input impedance and excellent drive efficiency.

Equivalent circuit

IGBT operation is best understood by again referring to the cross section of the device and its equivalent circuit shown in Fig.5. Current flowing from collector to emitter must pass through a pn junction formed by the P+ substrate and n- epi layer. This drop is similar to that seen in a forward biased pn junction diode and results in an offset voltage in the output characteristic.

Current flow contributions are shown in Fig.5 using varying line thickness, with the thicker lines indicating a high current path. For a fast device, the N+ buffer layer is highly doped for recombination and speedy turn off. The additional doping keeps the gain of the PNP low and allows two-thirds of the current to flow through the base of the PNP (electron current) while one-third passes through the collector (hole current).

$R_{shorting}$ is the parasitic resistance of the P+ emitter region. Current flowing through $R_{shorting}$ can result in a voltage across the base-emitter junction of the NPN. If the base-emitter voltage is above a certain threshold level, the NPN will begin to conduct causing the NPN and PNP to enhance each other's current flow and both devices can become saturated. This results in the device latching on in a fashion similar to an SCR. Device processing directs currents within the device and keeps the voltage across $R_{shorting}$ low to avoid latching.

The IGBT can be gated off, unlike the SCR which has to wait for the current to cease, allowing recombination to take place in order to turn off. IGBTs offer an advantage over the SCR by controlling the current with the device, not the device with the current. The internal Mosfet of the IGBT when gated off will stop current flow and at that point, the stored charges can only be dissipated through recombination.

The IGBT's on-voltage is represented by the sum of the offset voltage of the collector base junction of the PNP transistor, the voltage drop across the modulated resistance R_{mod} and the channel resistance of the internal Mosfet. Unlike the Mosfet where increased temperature results in increased $R_{DS(on)}$ and increased forward voltage drop, the forward drop of an IGBT stays relatively unchanged at increased temperatures.

Switching speed

Until recently, slow turn-off speed limited IGBTs from serving a wide variety of applications. While turn-on is fairly rapid, initial IGBTs had current fall times of around three microseconds. The turn-off time of an IGBT is slow because many minority carriers are stored in the n- epi region. When the gate is initially brought below the threshold voltage, the n- epi contains a very large concentration of electrons and there will be significant injection into the P+ substrate and a corresponding hole injection into the n- epi. As the electron concentration in the n-region decreases, electron injection decreases, leaving the rest of the electrons to recombine.

Therefore, the turn-off of an IGBT has two phases: an injection phase where the collector current falls very

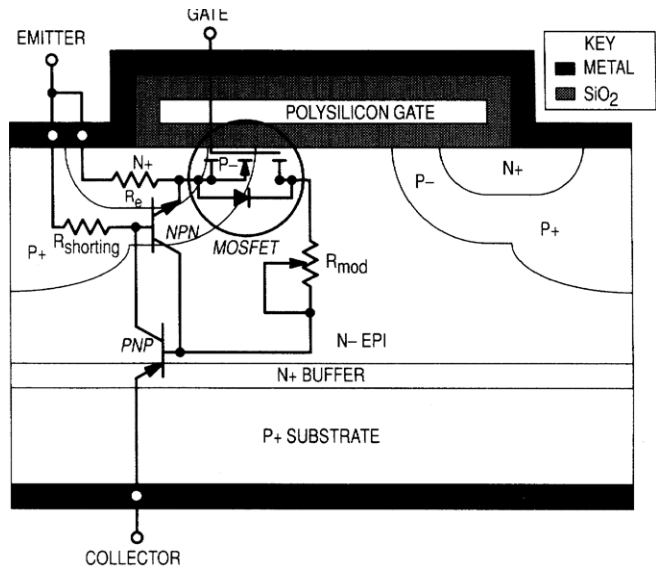


Fig.9: cross-section and equivalent schematic of a short circuit rated IGBT cell.

quickly and a recombination phase in which the collector current decreases more slowly.

Fig.8 shows the switching waveform and the contributing factors to tail time of a "fast" IGBT designed for PWM motor control. In power Mosfets, the switching speed can be greatly affected by the impedance in the gate drive circuit and the same rules apply to IGBTs.

Comparing IGBTs, BJTs & Mosfets

The conduction loss of BJTs and IGBTs is related to the forward voltage drop of the device while a Mosfet's conduction loss is based on $R_{DS(on)}$. Table 1 gives a comparison of turn-off and conduction losses at 10 amps for a power Mosfet, an IGBT and a BJT at junction temperatures of 25°C and 150°C.

Note that while the devices in Table 1 have approximately the same ratings, their chip sizes vary significantly. The bipolar transistor requires 1.2 times more silicon area than the IGBT while the Mosfet requires 2.2 times the area of the IGBT. This difference in die area has a direct effect on the cost of the devices.

At higher currents and high temperatures, the IGBT offers low forward drop and a switching time similar to the BJT without the drive difficulties. The lower conduction losses of the IGBT reduce power dissipation and heatsink size.

Thermal resistance

An IGBT and power Mosfet produced from the same size die have similar junction-to-case thermal resistance because of their similar structures.

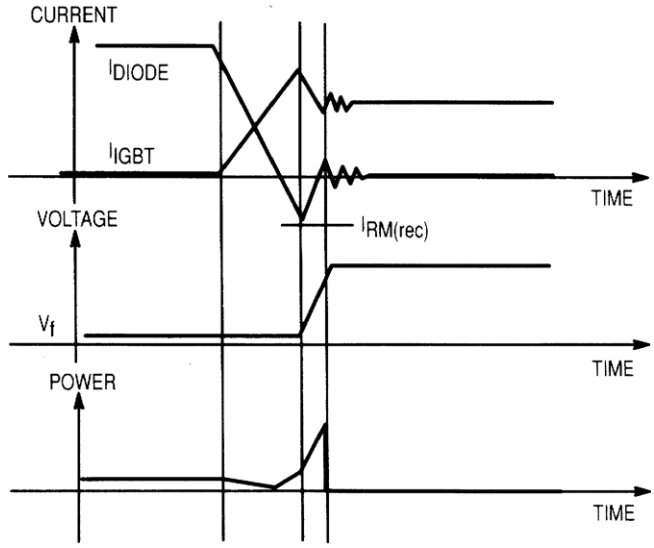
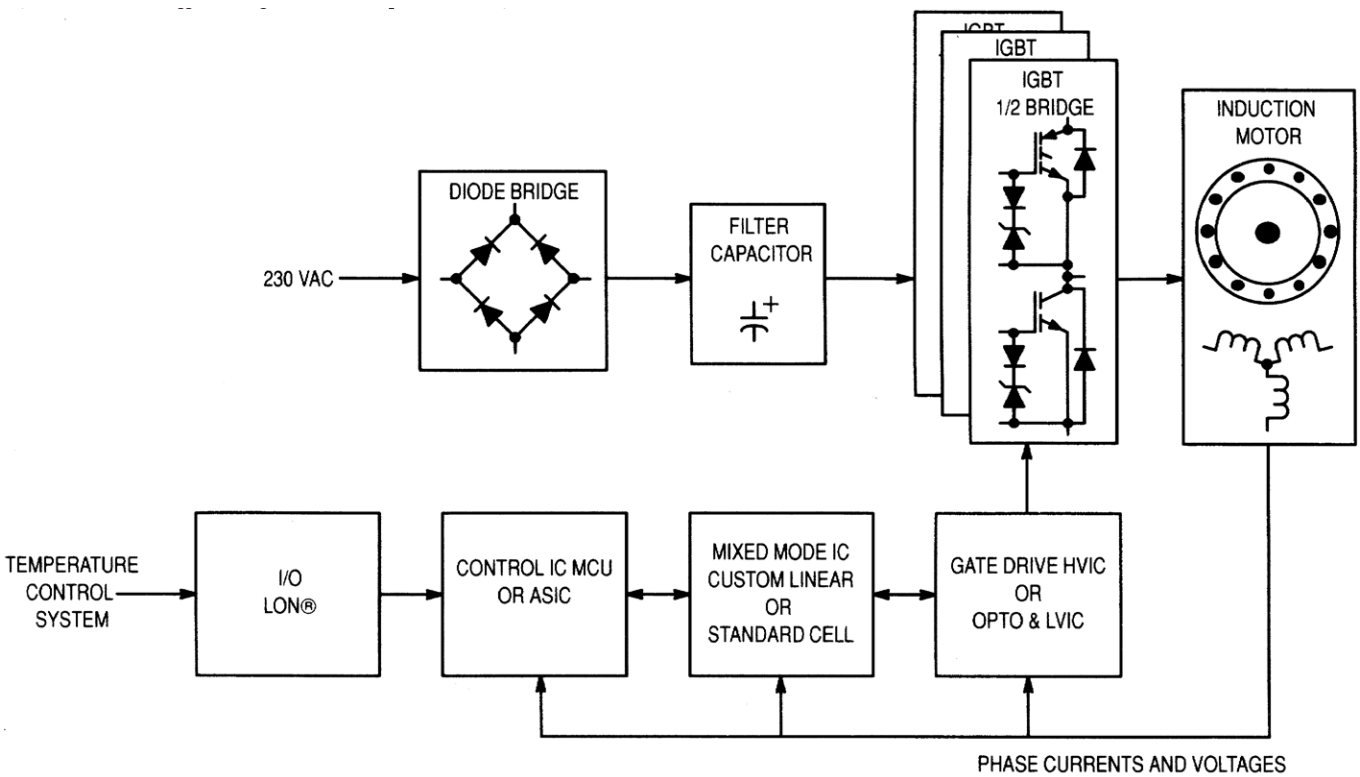


Fig.10: the waveforms associated with anti-parallel diode turn-off.

Short circuit rated devices

Using IGBTs in motor control circuit requires them to withstand short circuit current for a given period. Although this varies with the application, a typical value of ten microseconds is used for designing these specialised IGBTs. Notice that this is only a typical value given on the data sheet. IGBTs can be made to withstand short circuit conditions by altering the device structure to include an additional resistance (R_e, in Fig.9) in the main current path.

The benefits associated with the additional series



resistance are twofold.

First, the voltage created across R_e, by the large current passing through R_e, increases the percentage of the gate voltage across R_e, by the classic voltage divider equation. Assuming the drive voltage applied to the gate-to-emitter remains the same, the voltage actually applied across the gate-to-source portion of the device is now lower. This causes the device to operate in an area of the transconductance curve that reduces the gain and it will pass less current.

Second, the voltage developed across R_e results in a similar division of voltage across $R_{shorting}$ and V_{BE} of the NPN transistor. The NPN will be less likely to attain a V_{BE} high enough to turn the device on and cause a latch-up situation.

These two situations work together to protect the device from catastrophic failure. The protection period is specified in the ratings, giving the circuit time to detect a fault and shut off the device.

The introduction of the series resistance R_e also results in additional power loss by slightly elevating the forward drop of the device. However, the magnitude of short circuit current is large enough to require a very low R_e value. The additional conduction loss of the device due to the presence of R_e is not excessive when comparing a short-circuit rated IGBT to a non-short circuit rated device.

Table 1: Device Characteristics

Characteristic	TMOS	IGBT	Bipolar
Current Rating	20A	20A	20A
Voltage Rating	500V	600V	500V*
R(on) @ T_J = 25°C	0.2 ohms	0.24 ohms	0.18 ohms
R(on) @ T_J = 150°C	0.6 ohms	0.23 ohms	0.24 ohms**
Fall Time (typical)	40ns	200ns	200ns

* Indicates V_{CEO} rating ** BJT T_J = 100°C

Anti-parallel diode

When using IGBTs for motor control, designers have to place a diode in anti-parallel across each device in order to handle the regenerative or inductive currents of the motor. The optimal setup is to have the diode co-packaged with the device. A specific line of IGBTs has been created by Motorola to address this issue. These devices work very well in applications where energy is recovered to the source and are favoured by motor control designers.

Like the switching device itself, the anti-parallel diode should exhibit low leakage current, low forward voltage drop and fast switching speed. As shown in Fig.10, the diode forward drop multiplied by the average current it passes is the total conduction loss produced. In addition, large reverse recovery currents can escalate switching losses.

A secondary effect caused by large reverse recovery currents is EMI at the switching frequency and the frequency of the resulting ringing waveform. This EMI requires additional filtering in the circuit. By co-packaging the IGBT with its anti-parallel diode, the parasitic inductances that contribute to ringing are greatly reduced.

Induction motor drive

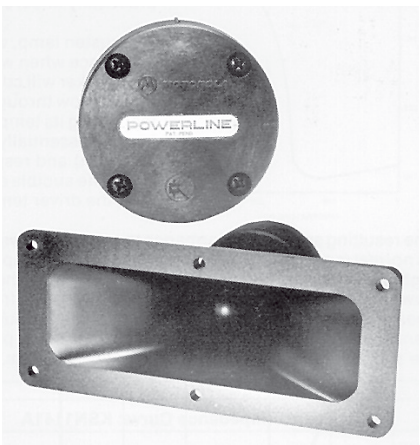
Mains operated, PWM variable speed motor drives are an application well suited for IGBTs. As shown in Fig.11, IGBTs may be used to directly control the voltage supplied to a 3-phase motor to control its speed. Depending on the application, the IGBT may be required to operate from the full-wave rectified mains supply.

Acknowledgement

This article reproduced by arrangement from Motorola Semiconductor Application Note AN1541. **SC**

THE "HIGH" THAT LASTS IS MADE IN THE U.S.A.

Model KSN 1141



The new Powerline series of Motorola's 2kHz Horn speakers incorporate protection circuitry which allows them to be used safely with amplifiers rated as high as 400 watts. This results in a product that is practically blowout proof. Based upon extensive testing, Motorola is offering a 36 month money back guarantee on this product should it burn out.

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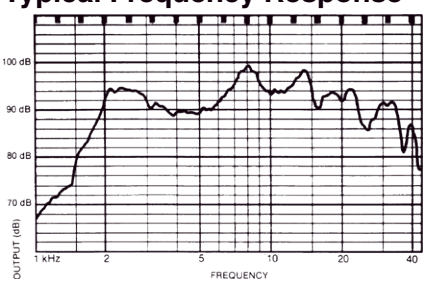
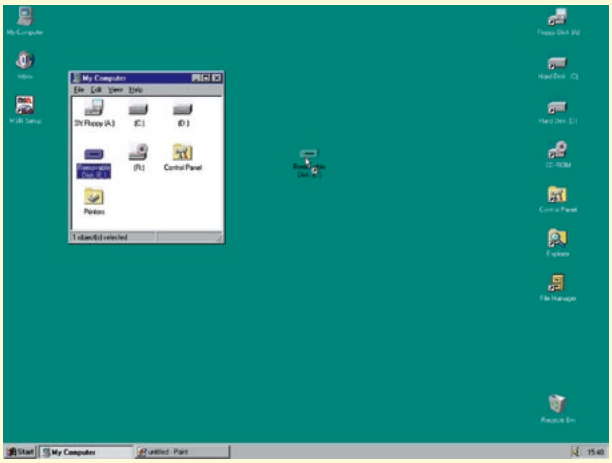
Max. Power Handling Capacity: 400W
Max. Temperature: 80°C
Typ. Imp: appears as a 0.3µF capacitor

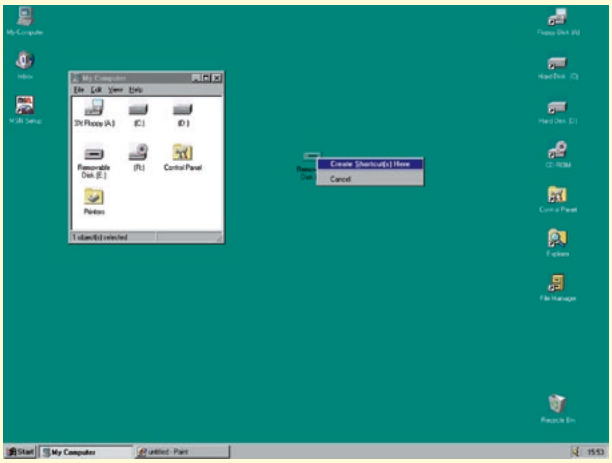
Typical Frequency Response



Creating shortcuts on the desktop



1: right click the item and drag it onto the desktop.



2: click "Create Shortcut Here" from the menu.

Computer Bits

Customising the Win95 desktop & start menus

The Windows 3.11 Program Manager is obsolete. In its place, Windows 95 presents a slick new interface that lets you place icons and folders directly on the desktop. Here's how to go about it.

By GREG SWAIN

Unlike its predecessor, the Win95 desktop can play host to virtually anything you care to drag there. While the Windows 3.11 desktop limits you to the Program Manager and the icons of minimised applications, the Win95 desktop is a far friendlier place to be.

Want to place shortcuts to your drives directly on the desktop? No problem – just open My Computer, right click (yes, right click) the relevant drive, drag it onto the desktop and release the mouse button. Choose "Create Shortcut Here" when the pop-up menu appears and there's your shortcut.

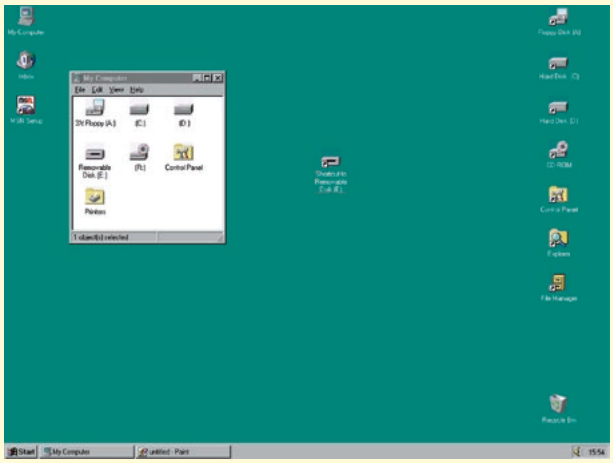
If you now double-click on the new shortcut icon, the Explorer opens to show the contents of the drive.

You can do exactly the same thing to folders (the new word for directories), applications or even individual files. All you have to do is launch the Explorer, right click on the appropriate folder, executable (exe) file or program file, and drag it onto the desktop. When the job is done, the application's icon appears on the desktop but with one minor difference – there's a little arrow to indicate that it is a shortcut to the application (see example at right).

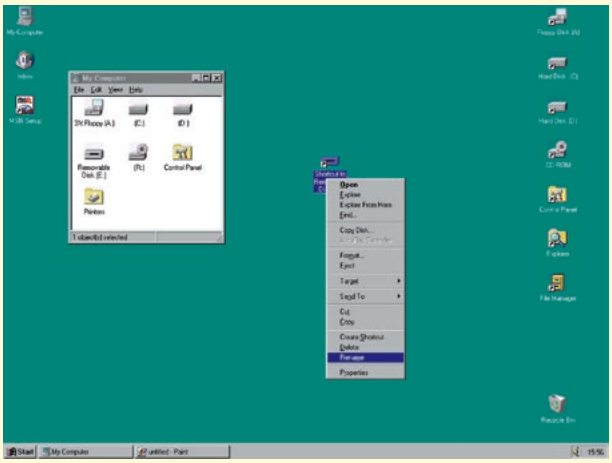
Don't clutter your desktop with shortcuts though. They should be reserved for your most frequently used applications. When you no longer want a particular shortcut on the desktop, just drag it to the Recycle Bin. Note that this gets rid of the shortcut only and not the original file or hardware item.

Renaming shortcuts

When you create a shortcut, Win95 automatically adds the words "Shortcut to" to the desktop icon; eg, "Shortcut to Explorer". However, the little

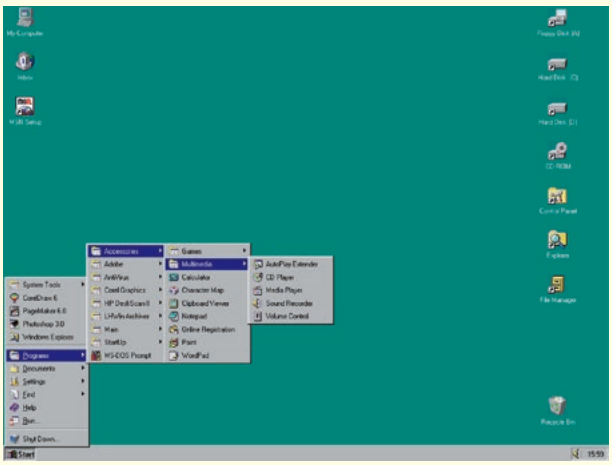


3: that's it – your shortcut appears on the desktop.

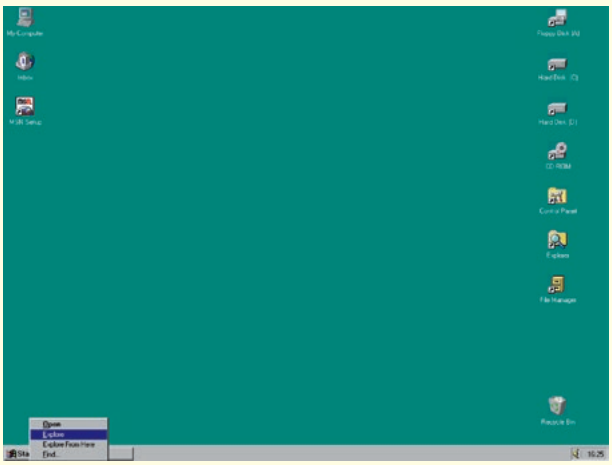


4: right-click the shortcut icon to rename it.

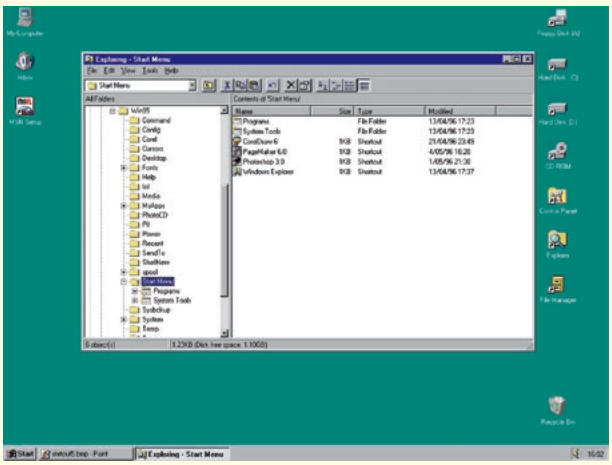
Rearranging the start menus



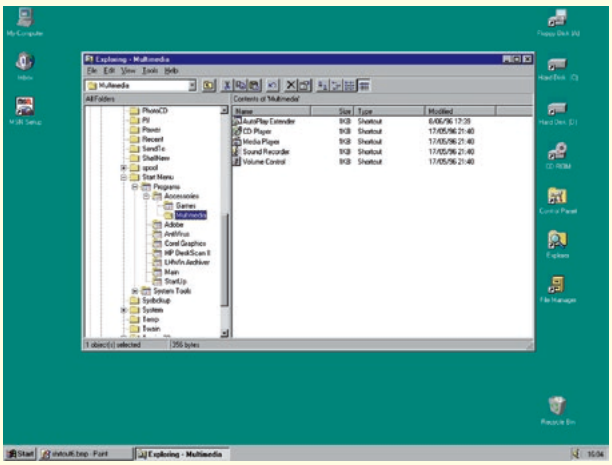
Problem: the CD Player entry is buried four menus deep.



1: right click the Start button, then left click "Explore".

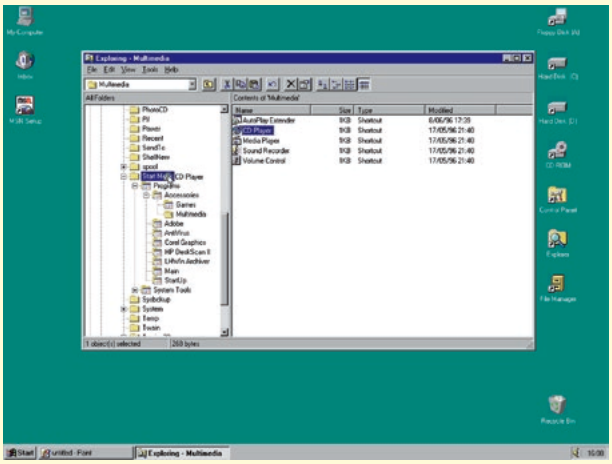


2: the Explorer opens at the Start Menu folder.

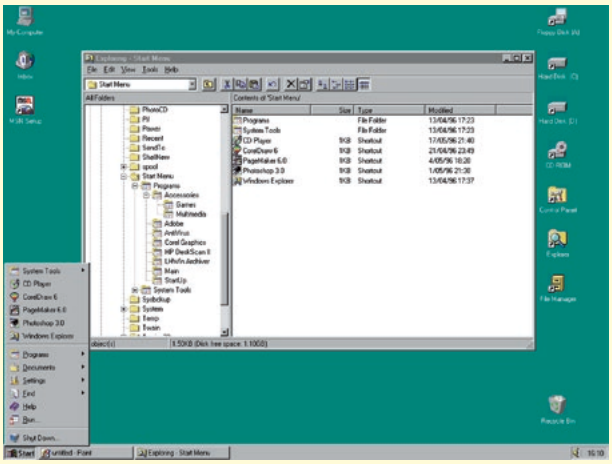


3: "drill" down to the Multimedia folder.

continued next page



4: left-click the CD Player shortcut and drag it onto the Start Menu folder.



5: now when you click the Start button, the CD Player entry appears in the first menu.

arrow that's added to the icon makes it obvious that it's a shortcut so these words are superfluous. Deleting them is easy – just right click on the icon and left click on "Rename" from the pop-up menu. It's now simply a matter of typing in the new name for the shortcut and left clicking off the icon.

By the way, get used to using the right mouse button when you install Windows 95. Right click on just about anything, including the Task Bar, and a menu pops up that lets you carry out certain functions. Unlike Windows 3.11, the right mouse button now actually does something useful and it's easy to use.

Rearranging the Start menus

Apart from using desktop shortcuts, applications are usually launched via the Start button. When you click the Start button, you navigate through a series of menus to the application you want.

Windows 95 automatically adds its own applications to the Start menus during installation. Any applications that you later install are also automatically added and these can even include entries for readme files or on-line registration of the software.

As a result, your Start menus quickly become cluttered with entries that are seldom (if ever) used. Worse still, an application that you use frequently can be buried three or four menus deep and drilling down to it each time you want to run it can become annoying.

Fortunately, it's easy to rearrange the Start menus to suit the way you want to work. The first thing to realise here is that the entries in the Start menus mirror the entries in the Start Menu folder and its sub-folders when you open the Explorer. The second thing to realise is that these entries are shortcuts and not the actual files themselves, as indicated by the little arrows attached to their icons.

What's the easiest way of getting to the Start Menu folder in the Explorer? Just right click the Start button and then choose "Explore" from the pop-up menu. From there, you can start exploring the contents of the Start Menu folder and its sub-folders.

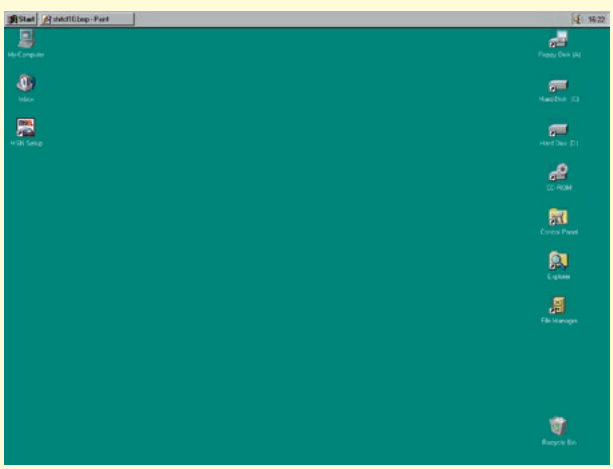
To delete an entry (eg, a readme shortcut), just drag it from the Explorer to the Recycle Bin. To move an entry, just left click it and drag it to its new location. Now, when you want to launch the application via the Start button, it will appear on the corresponding menu.

In the example given, the CD Player was buried four menus deep. By opening the Explorer and dragging the Shortcut entry directly to the Start Menu folder, it now appears on the opening menu. You can do this to any individual item or to groups of items.

Moving the status bar

Finally, if you don't like having the Task Bar along the bottom of the screen, left click it with the mouse and move it. It can be "snapped" into position along one side of the screen or along the top and your desktop icons will automatically adjust their positions to make room for it. **SC**

Moving the status bar



You can move the Task Bar to the top of the screen by left clicking on it and dragging it to its new location. It automatically snaps into place and the desktop icons move to make room for it.

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MECHANICAL TIMERS:** 55X48X40mm, 5mm shaft (Knob not supplied), two hours timing per 45deg. rotation, two 25V/16A SPST switches which close at the end of the timing period: **$5** ...**USED IEC LEADS:** Used Australian IEC leads: **$2.50 …STANDARD PIEZO TWEETERS:** Square, 85X85mm, 4-40KHz, 35V RMS: **$8,** Wide dispersion, 67X143mm, 3-30KHz, 35V RMS: **$9 …COMPUTER POWER SUPPLY:** Standard large supply as used in large computer towers, +5V/22A, +12V/8.5A, -5V/0.5A, -12V/0.5A, used but in excellent condition, guaranteed: **$30 …MAGNIFIERS:** Small eyepiece: **$3**, 30mm Loupe: **$8**, 75mm Loupe: **$12**, 110mm Loupe: **$15**, a set of one of each of these magnifiers (4): **$30 … NEW NICAD BATTERY BARGAIN:** 6 PACK (7.2V) OF 1.2V / 800 mAHr. 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Kit includes PCB, all on-board components, a speaker and Yes, the geiger counter tube is included: **$30 …RARE EARTH MAGNETS:** Very strong! 7X3mm **$2**, 10X3mm **$4**, Torroidal 50mm outer, 35mm inner, 5mm thick: **$10 …IR TESTER:** Kit includes a blemished IR converter tube as used in night vision and an EHT power supply kit, excellent for seeing IR sources, price depends on blemishes: **$30 / $40 …ARGON-ION HEADS:** Used Argon-Ion heads with 30-100mW output in the blue-green spectrum, power supply circuit provided, size: 350X160X160mm, weight 6Kg, needs 1KW transformer available elsewhere for about $170, head only for: **$350 …DIGITAL RECORDING MODULES:** Small digital voice recording modules as used in greeting cards, microphone and a speaker included, 6 sec. recording time: **$9 …WIRED IR REPEATER KIT:** Extend the range of existing IR remote controls by up to 15M and/or control equipment in other rooms: **$18 …12V-2.5W SOLAR PANEL KIT:** US amorphous glass solar panels, 305X228mm, Vo-c 18-20V, Is/c 200mA: **$22 Ea. or 4 for $70 …MIDI KEYBOARDS:** Quality midi keyboard with 49 keys, 2 digit LED display, MIDI out jack, Size: 655115X35mm, computer software included, see review in Feb. 97 EA: **$80**, 9V DC plugpack: **$10**, also available is a larger model which has mor features and has touch sensitive response keys: **$200 …STEREO FM TRANSMITTER KIT:** 88-108MHz, 6-12V DC supply, 8mA @ 9V, 25X65mm PCB size, PCB plus all on-board comp's, plus battery connector and 2 electret mic's: **$25,** plastic case to suit: **$4 …WOOFER STOPPER KIT:** Stop that dog bark, also works on most animals, refer SC Feb. 96, Kit includes PCB and all on board comp's, wound transformer, electret mic., and a horn piezo tweeter: **$39**, extra horn piezo tweeters (drives up to 4) **$6 Ea.** ...**ALCOHOL BREATH TESTER KIT:** Based on a thick film alcohol sensor. The kit includes a PCB, all on board comp's and a meter : **$30** ...**CENTRAL LOCKING KIT (NEW):** A complete central locking kit for a vehicle. The kit is of good quality and actuators are well made, the kit includes 4 actuators, electronic control box, wiring harness, screws, nuts, and other mechanical parts: **$60,** The actuators only: **$9 Ea.** ...**CODE HOPPING UHF CENTRAL LOCKING KIT PLUS A ONE CHANNEL UHF REMOTE CONTROL:** Similar to above but this one is wireless, includes code hoping Tx's with two buttons (Lock-unlock), an extra relay in the receiver can be used to immobilise the engine, etc., kit includes 4 actuators, control box, two Tx's, wiring harness, screws, nuts, and other mechanical parts: **$109 …ELECTROCARDIOGRAM PCB + DISK**: The software disk and a silk screened and solder masked PCB (PCB size: 105 x 53mm) for the ECG kit published in EA July 95. No further components supplied: **$10 …SECURE IR SWITCH:** IR remote controlled switch, both Rx and Tx have Dip switches for coding, kit includes commercial 1 Tx, Rx PCB and parts to operate a relay (not supplied): **$22 8A/4KV relay $3 …FLUORESCENT TAPE:** High quality Mitsubishi brand all weather 50mm wide Red reflective tape with self adhesive backing: **3 meters for $5 …LOW COST IR ILLUMINATOR**: Illuminates night viewers or CCD cameras using 42 of our 880nm / 30mW / 12 degrees IR LEDs. Power output is varied using a trimpot., operates from 10 to 15V, current is 5-600mA **…IR LASER DIODE KIT:** Barely visible 780nM/5mW (Sharp LT026) laser diode plus constant current driver kit plus collimator lens plus housing plus a suitable detector Pin diode, for medical use, perimeter protection, data transmission, experimentation: **$32 …WIRELESS IR EXTENDER:** Converts the output from any IR remote control into a UHF transmission, Tx is self contained and attaches with Velcro strap under the IR transmitter, receiver has 2 IR Led's and is place near the appliance being controlled, kit includes two PCB's all components, two plastic boxes, Velcro strap, 9V transmitter battery is not supplied: **$35**, suitable plugpack for the receiver: **$10 …NEW - LOW COST 2 CHANNEL UHF REMOTE CONTROL:** Two channel encoded UHF remote control has a small keyring style assembled transmitter, kit receiver has 5A relay contact output, can be arranged for toggle or momentary operation: **$35** for one Tx and one Rx, additional Tx's **$12** Ea.

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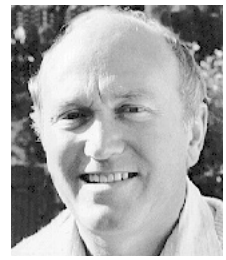
VINTAGE RADIO

By JOHN HILL



A rummage through my junk

Although I have been to many swap meets of various kinds, the last one I attended was special because it was a vintage radio swap meet. It was held in Melbourne and was very well attended. What's more, I had taken a site at the meet for the express purpose of selling some of my junk.

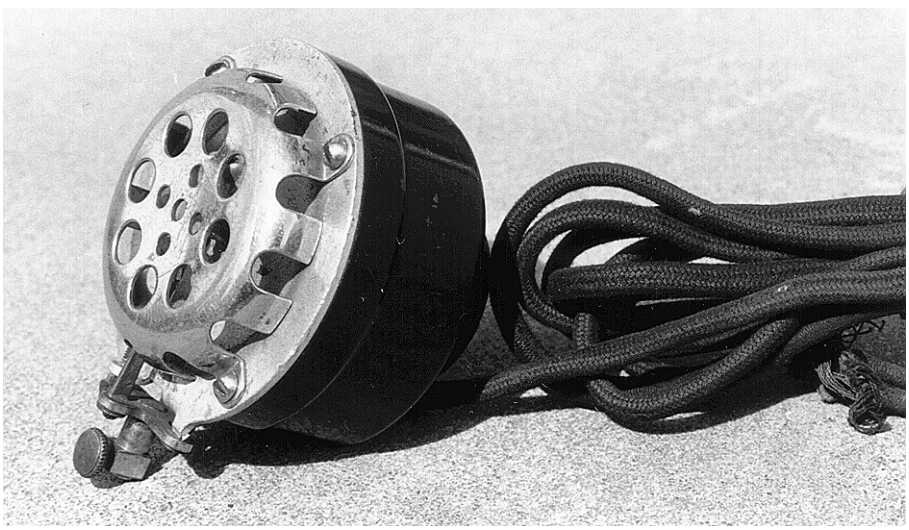
There is one serious problem associated with collecting and that is the slow but steady accumulation of bits and pieces over the years. As most readers would know, some of these bits and pieces are extremely valuable and supply restorers with many otherwise unobtainable spares. But it gets out of hand after a while, so I decided to be ruthless and off-load some of my junk so that I could to take possession of my shed again. The swap meet seemed like an appropriate place for its disposal.

Sifting through the rubble was great fun and all sorts of things were found that had been completely forgotten. When sorting through these treasures, it was initially a case of "no, I shouldn't sell that", or "I must keep those", or "these may come in handy", and so on. So, by the end of the day, hardly a thing had been set aside for the big sale. As a result, the process had to be repeated with a little more resolve.

My scrounging uncovered a few interesting relics. As some which I earmarked to sell are fairly rare and likely be of interest to readers, it seemed like a good opportunity to photograph them and write them up for Vintage Radio. Even though these things are quite collectable, I had no real use for them and the larger items were only taking up valuable space.

The first of these interesting items is a magnetic pick-up head for 78rpm recordings. This particular pick-up was specially made to fit onto the tone arm of an acoustic phonograph, thus allowing records to be played through a radio receiver.

While playing the family phonograph through a radio was common practice in the late 1920s and early 1930s, it was usually done using a complete pick-up with an accompanying volume control. A pick-up head only that fitted on to the phonograph's tone arm would have been a less expensive option. However, its very long, unshielded lead to the receiver may have caused some hum problems.



This old magnetic pick-up was made to fit straight onto the sound arm of an acoustic phonograph.

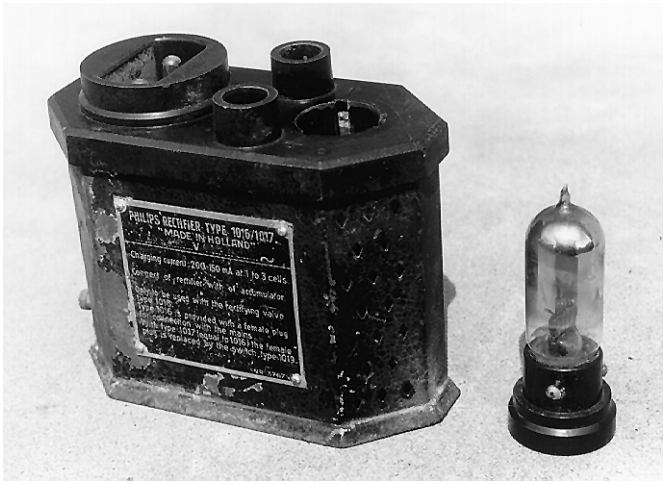
Battery eliminator

The next item is from 1927 and is a "B" battery eliminator. These units were usually large and heavy and this Australian-made Emmco was no exception. It uses a cold cathode rectifier and supplies a range of "B" voltages only. Some eliminators incorporated "C" voltages as well.

While the "B" battery eliminator solved the expense of frequent "B" battery purchases, the rechargeable lead acid "A" battery was another problem in that it required recharging at regular intervals, which was fairly inconvenient.

Shown in one of the accompanying photographs is a Philips "A" battery trickle charger. Its job was to slowly and continuously recharge the "A" battery – hopefully at a rate which

This photo shows an Emmco "B" battery eliminator. It used a cold cathode rectifier and had three output voltages, two of which could be varied using the large knobs on the top of the unit.



A Philips "A" battery trickle charger. The rectifier valve (right) plugs into the large hole at top right, while the two smaller holes are for the battery leads. Power is applied to the socket on the left.

approximated the discharge rate/period – and eliminate the irksome task of carting the battery off to the nearest garage or battery service centre.

Of course, neither the "B" battery eliminator nor the "A" battery trickle charger were of any use unless 240V AC power was available. Back in the 1920s, only the cities and larger towns had AC electric power and out in the country, beyond these supply systems, receivers still used batteries, just as they had done since radio first began.

Radio had not been with us long when someone reckoned that having one in their car would be a great idea. The vibrator unit was the big breakthrough in battery powered receivers because it allowed a radio to operate on a single battery – usually a 6V or 12V lead acid type. A vibrator, in conjunction with a special transformer and a rectifier valve, was the heart of car radio receivers up until about 1960.

But there were a few car radios before the vibrator came on the scene. These receivers still required a high tension supply and it was obtained from a motor/generator set (a low-voltage electric motor driving a high-voltage generator). These devices produced quite high voltages – up to 180V in the case of the Emerson unit shown in one of the accompanying photographs.

No doubt the engineering involved in manufacturing a motor/generator was considerable and its cost was probably equal to that of the receiver itself.

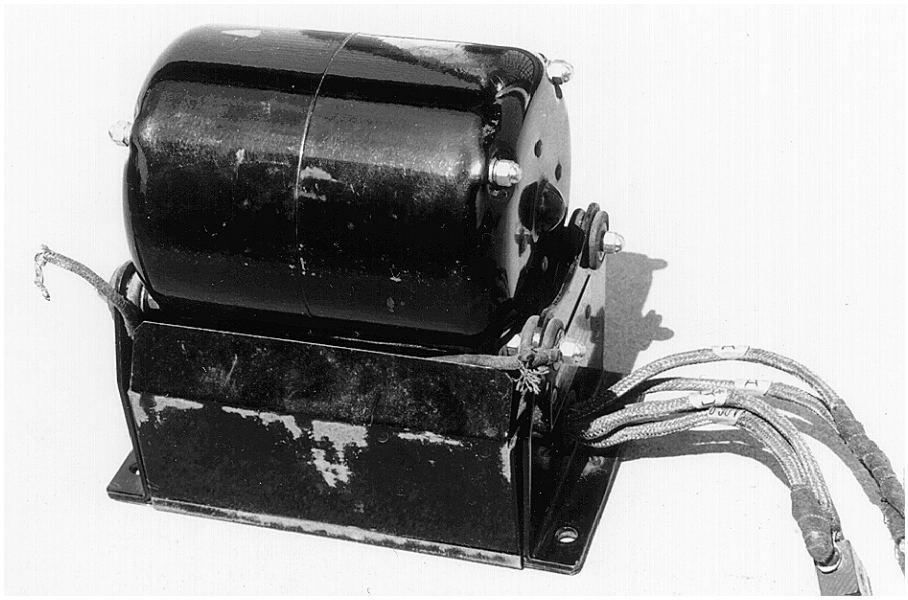
It is amazing how many ingenious and well designed products appeared in the early days of radio, only to be rendered totally obsolete in a very short time. The car radio motor/generator unit would be a classic example of instant obsolescence once the vibrator arrived on the scene.

(Editorial comment: although the motor generator had only a short life in car radio applications, larger versions were used extensively by the armed forces during World War ll and beyond – until the end of the valve era, in fact. They were woefully inefficient devices. One of the top brands, the "Genemotor", could boast an efficiency of only 30% but this was not regarded as a serious problem for military applications).

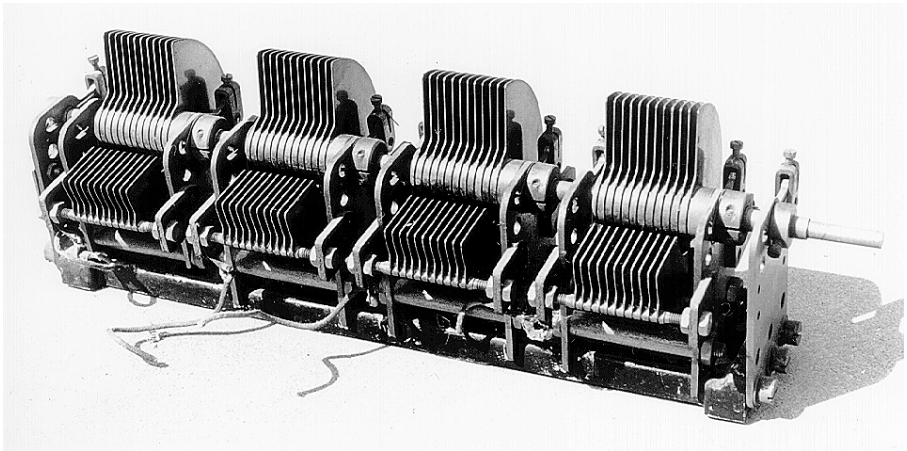
4-gang capacitor

Shown in one of the photographs is a 4-gang tuning capacitor from an ancient TRF receiver. After the superhet became established, tuning capacitors were mainly two and 3-gang types but some of the old TRF capacitors were four and 5-gang units.

This old 4-gang capacitor is quite large, as was the norm back then, and is made entirely of brass. Finding a practical use for such a monstrosity is



This elaborate device was used to power early car radios. Made by Emerson, it consists of a low voltage DC electric motor driving a high voltage DC generator. It was capable of producing 180V at 80mA. The advent of the vibrator rendered these monstrous things obsolete for car radios.



A 4-gang tuning capacitor from an ancient TRF receiver. It is made entirely of brass and the main control shaft rotates on plain bearings.

fairly unlikely but it is an interesting relic and would make a good display item.

Another piece of equipment that had been collecting dust for a few years is a 1930s Pilot valve tester. It was bought with the intention of restoring it and although it is in working condition, the old Pilot has few problems.

First, there are no operating instructions, which is usually the case with old valve testers. Second, being a 1930s model, there is no provision for testing post-war 7-pin and 9-pin miniature valves, unless one makes up a few adaptors. And finally, because the tester is of American manufacture, it works on 110V and so requires a step- down transformer for its operation.

While there would be few problems cleaning up the sockets and switches, I already have other valve testers, with operating instructions, and there seemed little point in keeping this one. Although the Pilot is usable on early valves up to octal, perhaps it too would be better used as display item than as a working valve tester.

The big swap meet bargain of bargains was a selection of unique valves. These valves are so unique that one can only wonder what their intended use was! The type numbers are absent from any of the common valve catalogs.

Even the bargain price of $1 each, or $20 a box full, was initially too high to tempt much interest. But at the end of the day someone realised their true worth and took the lot.

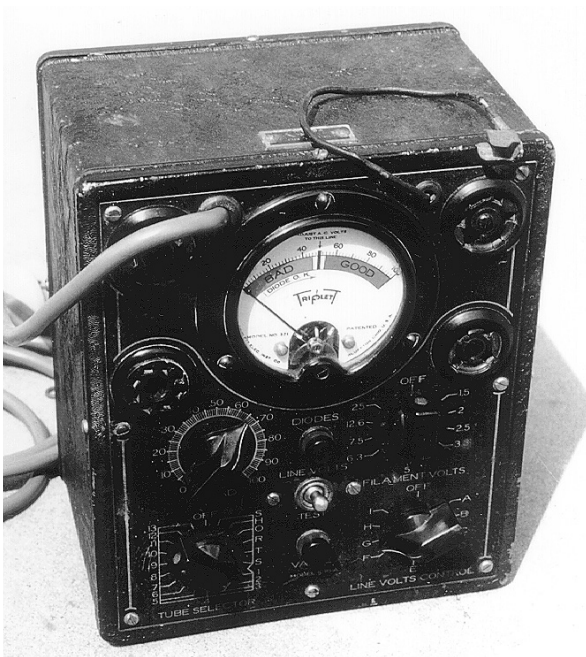
Why sell?

Anyone attending a radio swap meet must wonder why other collectors want to unload so much of their wares! If it is so good, why don't they keep it?

The answer is simple. If a collector has something he really has no use for, or he has duplicates of a particular item, then the answer is to swap, trade or sell. That way, other things can be acquired without having to spend money. It also prevents the accumulation of unwanted junk.

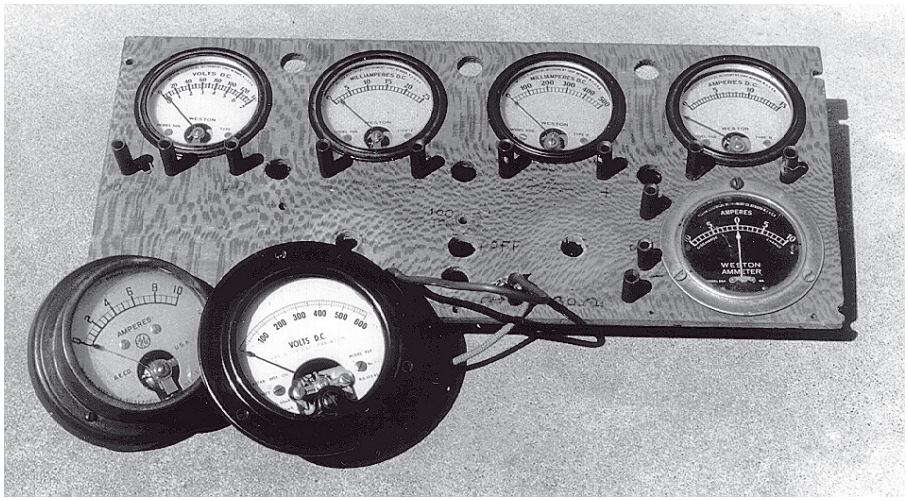
One interesting aspect of a swap meet is to see what people pay for the things they want. Most members of the community would take these items to the tip and consider them to be rubbish. Who knows – maybe they're right!

To be perfectly honest, after collecting for more than 10 years, I'm starting to look on some quite collectable receivers as just old radio sets. There is no reason why I should collect every



This valve tester was one of a trio of test instruments. Presumably the other units were a radio frequency generator and a volt/ohms/amp meter. Lack of instructions and 110V operation makes it fairly unattractive for use as a valve tester.

While this neat little 1920s receiver looks OK on the outside, there was quite a lot missing on the inside. It now has a new owner.



There's not much use for old meters such as these now that cheap multimeters are so readily available. In the distant past, this panel had been used as a volts/amp test rig.

make and model, nor is there any reason to have the best of everything.

There is every possibility that over the next 10 years I will gradually scale down my collecting activities and reduce the size of my collection, keeping only the more interesting items. I can't take it all with me when I go, can I?

Other throw-outs

I'm getting a bit off the track here. Let's get back to clearing out my shed.

One of my other throw-outs was a 1920s 3-valve regenerative receiver in a neat little cabinet with double doors at the front, covering the control panel. I was told it is a Radiola 4 cabinet into which someone had built the 3-valve set. Whether that was the case or not it sold quickly and now has a new owner.

Naturally it had been my intention to restore the little 3-valver but, as there are better and more interesting old regenerative sets in the shed, I decided to let this one go.

Accompanying the 3-valve receiver was a 1926 Brown horn speaker. Horn speakers are very collectable and although this particular example was a bit battle scarred it, too, sold quickly. There are two others in the shed and, when all is said and done, how many Brown horns does a bloke need?

Now some of my junk was not really junk at all but quite nicely restored radio receivers and about half a dozen mantel radios from the 1940s and 1950s. Once again, some were duplicates and I see no need to collect radios in twos or threes unless one is into collecting a complete colour range of a particular model.

This Brown horn speaker is one of the better types in that it has an aluminium cone instead of the usual soft iron diaphragm. Its tonal qualities and sensitivity were better than most.

The restored radios sold very well, as they were considerably cheaper than those at some of the other sites. Anything at a fair price will sell. Inflate the price beyond the item's true worth and not many buyers will be forthcoming. I went to the swap meet to sell, not to bring it all back home again at the end of the day.

So all things considered, taking a site at the vintage radio swap meet proved to be a worthwhile move for several reasons. It was not only a good day out whereby I off-loaded some unwanted equipment but I also met other collectors whom I would not have otherwise met. **SC**

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PRODUCT SHOWCASE

6/12V Automotive Battery Tester

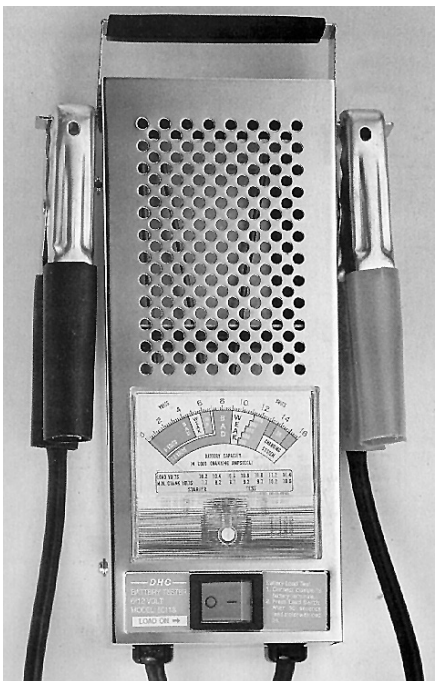
Just how do you check out your car's battery? Unless you try to start your engine on a very cold morning you really don't know if the battery is up to standard. And when that cold morning arrives, the battery may fail when called upon to do its job.

That's where the Model 50113 battery tester from Jaycar can be handy. It can check the battery's state by monitoring the voltage with no load and with a 100-amp load, to simulate the loading of a typical starter motor when cranking the battery.

As well as a voltage scale up to 16V, the unit has a colour scale which grades 6V and 12V batteries in terms such as "bad", "weak" and "OK", as well as having a scale which correlates the voltage under load of a 12V battery to "cold cranking amps". This is a measure of the battery's ability to crank the engine when the temperature is under 5°C. According to the manual which comes with the tester, a typical fully charged battery at 5°C has only 40% of the capacity that it possesses at 25°C.

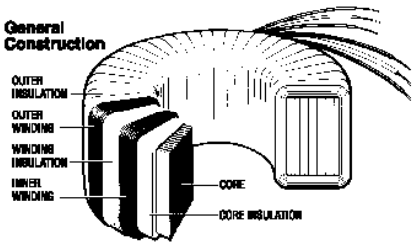
In practice, the tester is connected directly across the battery and the voltage is noted. The red rocker test button is then pushed for 10 seconds and the reading on the scale noted. If the needle is in the red region, the battery is a dud. Unfortunately, two of the heavy duty batteries used in our lab were found wanting in this test; luckily we were not depending on them to start a car!

The tester becomes quite warm after a load check, as you might expect because it has to dissipate something in the region of 1000 watts. For this reason, only three such tests are permissible in a 5-minute period.



The tester appears to be well made and is easy to use. It is available from all Jaycar Electronics stores and resellers for $89.95. (Cat QM-1620).

TOROIDAL POWER TRANSFORMERS



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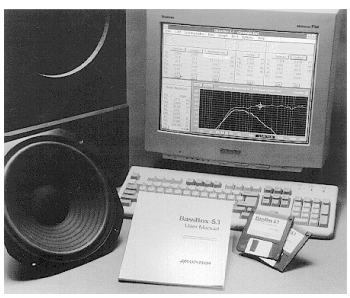

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TES sound level meter

How quiet is your office or working environment? For the safety of your hearing you should not be exposed to noise levels of more than 85dBA for long periods at a time. Many factory environments are much noisier than this and safety muffs are regarded as more or less mandatory in such situations.

Many other working environments are also quite noisy and are a cause for concern. Your own home can also be a hearing hazard, particularly with such appliances as food mixers and blenders, vacuum cleaners and even hair-dryers. Many of these can exceed 90dBA and you would be required to wear hearing protection under normal conditions of employment. And most power tools are exceedingly noisy.

Want to check out your own situation? This TES 1350 sound level meter will do the job. It has a calibrated inbuilt electret microphone and a 4-digit liquid crystal display which reads in dB with either "A" or "C" frequency weighting.

The TES 1350 has two ranges: Lo, reading from 35-100dB; and Hi, reading from 65-130dB. The meter response can be switched to slow or fast and there is a hold facility to catch noise peaks. In addition, there

is an inbuilt oscillator which provides a reference signal for calibration. This is brought into play by setting the function slide switch to CAL and then tweaking the adjacent trimpot to give a reading of 94dB.

The other worthwhile feature of the instrument is that it has a 3.5mm stereo jack socket which provides two output signals for use with external equipment. One is an AC output with an impedance of 600Ω while the other is a DC logarithmic signal corresponding to 10mV/dB. The unit is powered with a standard 9V battery with an expected life of 100 hours (using an alkaline type).

The TES 1350 is available at $399 from Altronics, 174 Roe St, Perth WA 6000. Phone 1 800 999 007.

If you are seeing a blank page here, it is more than likely that it contained advertising which is now out of date and the advertiser has requested that the page be removed to prevent misunderstandings. Please feel free to visit the advertiser's website:
www.emona.com.au/

Spectrum analysers from Promax

The Promax range of spectrum analysers is available from Emona Instruments. There are three instruments in the range covering the frequency range up to 1GHz or with an option to cover up to 1.75GHz, which takes in the satellite TV IF band.

Key features of the instruments are automatic selection of the optimum resolution bandwidth, switchable input impedance of 50Ω or 75Ω, indication of frequency on a 4½ -digit display, total dynamic range of 120dB and built-in calibration.

They offer three vertical axis settings of 2dB/div, 10dB/div and linear

detection. Measurement range is 15dBμV to 130dBμV.

For further information, contact Emona Instruments. Phone (02) 519 3933; fax (02) 550 1378.

Audiosound home cinema speakers

Audiosound Laboratories has developed three home theatre speaker system packages which include their new CE-1 passive equalised centre channel speaker with double magnetically shielded drivers.

System One is very unobtrusive and uses the Audiosound space-bass system incorporating two subwoofers. The total package comprises seven loudspeakers in all for under $2000.

The tiny front and rear speakers come with wall mounting brackets and can be colour-matched to order for a highly unobtrusive total system.

System Two (pictured) uses the floor-standing 8015s up front, with their Piccolo system for rear channels and the CE-1 for the centre. The main 8015s have received an Australian Design Award and this complete package is well priced at $1890. System Three is similar to System Two and the same price but uses the unobtrusive DM-1s instead of the Piccolos for the rear channels.

Audiosound are also able to supply complete home theatre packages including Dolby Pro Logic receivers and large screen TVs to match.

For further information, contact Audiosound Laboratories, 148 Pitt Rd, Curl Curl, NSW 2099. Phone (02) 9938 2068.

Miniature DC motor can be sterilised

Designed for medical, surgical and chemical applications, the Maxon RE 035 40-watt and 2326 6-watt DC motors can be repeatedly sterilised in an autoclave. Dismantling is not necessary. They have ironless rotors and are intended for use in medical hand tools such as bone saws, drilling and milling machines, dental and dermatological equipment, infusion pumps, therapeutical assistance devices, and analytical and dialysis equipment.

Both can be vapour sterilised to 135°C and are pressure insensitive to 3.6 bar in 100% relative humiity. The 40-watt RE035 has a diameter of 35mm, is 71mm long and has an efficiency of 82%. The smaller 6-watt model is 26mm in diameter, 44mm long and has an efficiency of 75%. Both are easy to speed control and have a speed range from 0-11,000 rpm.

For further information, contact M. Rutty & Co, 4 Beaumont Rd, Mt Kuringai, NSW 2080. Phone (02) 457 2222.

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- FMTX10B $2599: same as rack mount version but also includes dual SCA coder with 67 & 92kHz subcarriers.

AUDIO

- DIGI-125 Audio Power Amp: this has been the most popular kit of all time with some 24,000 PCBs being sold since 1987. Easy to build, small in size, high power, clever design, uses KISS principle. Manufacturing rights available with full technical support and PCB CAD artwork available to companies for a small royalty. 200 Watt Kit $29, PCB only $4.95.
- AEM 35 Watt Single Chip Audio Power Amp $19.95: this is an ideal amp for the beginner to construct; uses an LM1875 chip and a few parts on a 1 inch square PCB.
- Low Distortion Balanced Line Audio Oscillator Kit $69: designed to pump out line up tone around studio complexes at 400Hz or any other audio frequency you wish to us. Maximum output +21dBm.
- MONO Audio DA Amp Kit, 15 splits: $69.
- Universal BALUN Balanced Line Converter Kit $69: converts what you have to what you want, unbalanced to balanced or vice versa. Adjustable gain. Stereo.

COMPUTERS

- Max I/O Card for PCs Kit $169: originally published in Silicon Chip, this is a real low cost way to interface to the outside world from your PC, 7 relays, 8 TTL inputs, ADC & DAC, stepper motor drive/open collector 1 amp outputs. Sample software in basic supplied on disk.
- IBM PC 8255 24 Line I/O Card Kit $69, PCB $39: described in ETI, this board is easy to construct with only 3 chips and a double sided plated through hole PCB. Any of the 24 lines can be used as an input or output. Good value.
- Professional 19" Rack Mount PC Case: $999.
- All-In-One 486SLC-33 CPU Board $799: includes dual serial, games, printer floppy & IDE hard disk drive interface, up to 4Mb RAM 1/2 size card.
- PC104 486SLC CPU Board with 2Mb RAM included: 2 serial, printer, floppy & IDE hard disk $999; VGA PC104 card $399.

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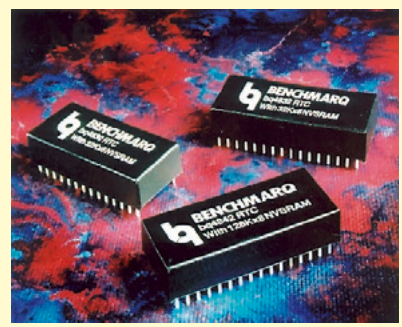
KITS-R-US sell the entire range of designs by Graham Dicker. The designer has not extended his agreement with the previous distributor, PC Computers, in Adelaide. All products can be purchased with Visa/Bankcard by phone and shipped overnight via Australia EXPRESS POST for $6.80 per order. You can speak to the designer Mon-Fri direct from 6-7pm or place orders 24 hours a day on: PH 018 80 6794; FAX 08 270 3175.

Static RAM has on-board battery



A new range of modules from Benchmarq incorporate a static RAM with on-board battery, real-time clock and CPU supervisor and directly replaces industry standard 28-pin static RAMs. In effect, the Benchmarq bq4830 provides non-volatile static RAM by combining an internal lithium battery with a 32K x 8 CMOS SRAM, a quartz crystal clock and a power-fail chip. It provides 10-year minimum data retention and unlimited write cycles.

The bp4832 provides full CPU supervision plus the features of the bp4830 in a 32-pin package. It provides a watchdog timer, power-on reset, alarm/periodic interrupt, power-fail and low battery warning. The bp4842 has all the features of the bp4832 but is a 128K x 8 SRAM as well.

For further details, contact Reptechnic, 3/36 Bydown St, Neutral Bay, NSW 2089. Phone (02) 9953 9844; fax (02) 9953 9683.

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Write to: Ask Silicon Chip, PO Box 139, Collaroy Beach, NSW 2097.

Slo-blo fuses not desirable

I am keen to buld the 175W amplifier module described in the April 1996 issue of SILICON CHIP. However, a mate of mine suggested that it should be fitted with slow-blow fuses in the supply lines to avoid the nuisance of fuses blowing at inconvenient times. I notice that you have not specified a particular type of fuse in the parts list, so should I take my mate's advice. (B. L., Campsie, NSW).

• While the transistors in this module are quite rugged, there is only one line of protection in the circuit – the fuses. If the current gets to the point where the fuses should blow, you don't want any delay, otherwise the transistors will blow before the fuses. In fact, as a general rule, fuses which protect semiconductor circuits should alway be standard fast-blow types.

Slow-blow fuses are normally specified only where the component to be protected can easily withstand large current overloads and is subjected to them in normal operation. In such cases, a normal fuse would be subject to nuisance blowing. A good example of this is with large toroidal power transformers which draw a large initial surge current. See our article on fuses for these transformers in the March 1995 issue of SILICON CHIP.

Having poo-poohed slow blow fuses, we are planning a PA version of this 175W amplifier and it will incorporate short circuit protection.

Colour TV pattern generator

I have just completed building the Colour TV Pattern Generator and have run into some problems.

First off, I'm operating the unit via a variable-voltage battery eliminator plugpack. This unit supplies DC at 3, 4.5, 6, 7.5, 9 and 12V at 300mA. I hope this has nothing to do with the fault I'm about to describe. It took me the better part of two days to construct the kit and what seemed like 4 or 5 hours wiring in those bridging connections (if I never see another bridge again, it'll be too soon).

I took every precaution to ensure that all the components were wired in correctly, especially the electrolytic capacitors, diodes and such where polarity is important. When I finally got to test the system, I found I could get the Check, Hatch, Dot and White Raster OK but the Red Raster and Colour Bars/Greyscale would not operate properly. The Red Raster was erratic and the Colour Bars weren't there at all; neither was the Greyscale.

I said the first four operated OK, although not absolutely perfectly because a descending horizontal line would appear across the screen and where it appeared, the pattern would appear to bend behind it. Are there any component value changes I should be aware of (resistors, capacitors) or any other components that might have been supplied that were wrong for this kit?

My purpose in constructing this kit is not for TV servicing work but to insert colour bars at the head of, between items and on the tail-end of videocassettes recorded off-air or from a video camera. (N. F., Stockton, NSW).

• It is important that the plugpack is rated at 500mA to prevent the regulator (12V) from dropping out and producing mains hum in the supply. A larger value electrolytic than the 470uF capacitor at the input to REG1 will also help.

Problems with the greyscale and colour bars can be caused by IC14 not oscillating or IC15 not counting. Also check that IC13b has a high Q output at pin 9 when the bars are selected by switch S2a.

Speed control for cassette recorders

I am teaching myself to play the mandolin and find it helpful trying to play along with a tape cassette and recordings. The problem is that many recordings are not in an exact key; ie maybe a quarter of a note sharp or flat of a true key (such as half way between A and A#). I therefore need a system to slow or speed the cassette motor up by only a small frequency shift.

If there is no easy way, perhaps you could publish some details on the theory of tape motor control. (C. F., Cringila, NSW).

[dot]In most tape recorders the capstan motor is a DC type with some sort of tachometric speed control via an extra pair of windings. In some cases, if you have access to the circuit diagram, it may be possible to use a trimpot to vary the tacho signal, and thereby the speed of the motor.

Failing that, you could decide to separately power the capstan motor via an external speed control circuit. This might not have the same degree of speed regulation but at least you would be able to control it yourself.

As a starting point, you might consider the speed control published on page 15 of the August 1992 issue.

Cat deterrent not humane

May I suggest a project which would, I believe, be of great practical use. There are reports that bells around cats' necks do little or nothing to prevent the slaughter of native animals and birds by family pets, put out, as is usual, at night.

My idea would be for a small electronic unit to be worn by the cat, continuously emitting a pulsed tone at a supersonic frequency but within the audio frequency range of small mammals and birds.

Questions on digital signal generator

Would you please supply me with some information on the Digital Signal Generator kit published in the July 1990 issue of SILICON CHIP. I don't have access to the article and am totally ignorant on its internal workings. I am assuming that in its 10Hz-1000Hz range it displays frequency in 1Hz increments. I would like to know if it actually generates frequency in between these 1Hz increments such as 30.25Hz or 30.2Hz etc.

I need an affordable signal generator that can do this and at the same time have solid amplitude stability. I will be using it in establishing the Thiele-Small loudspeaker parameters and driver/box design. (S. W., Modbury North, SA).

• The frequency output of the Digital Signal Generator is continuously adjustable over its entire range from 0.1Hz to 500kHz but its display only has 4-digit resolution. This has two ramifications. First, on the 10Hz to 1000Hz range, it should display frequencies between 9.9Hz and 999.9Hz although the actual range will depend on the initial setup of the instrument.

Second, the accuracy of the frequency display is ±2% + 2 digits which means that a frequency readout of 512.5Hz is not an absolute figure; the actual frequency could be anywhere between 500Hz and 523Hz.

And while the frequency can be varied continuously, it is doubtful whether the mechanical resolution of the potentiometers would let you reliably and repeatedly set a particular frequency of, say, 512.5Hz. And even if you did manage this feat, it is doubtful whether the frequency stability of the instrument would be able to hold that particular figure for any length of time, say 15 minutes.

In any case, you don't need great frequency accuracy if you are working out Thiele-Small parameters. A figure of ±2% would be quite adequate. When measuring speaker resonances, it is not possible to determine them with great accuracy since they vary with the amplitude of the drive signal, the temperature and with the age of the speaker. The digital signal generator is certainly adequate for this task.

If you really needed the degree of frequency accuracy and stability you describe, you would have to pay many thousands of dollars.

I don't know what the frequency would be but perhaps someone has done or could do a few experiments, using the silent dog whistle as a starting point. A frequency that is inaudible to the cat but audible to its prey would be the ideal.

As the range would need to be only a few feet, the output power should be low and could, I hope, be supplied by one of the larger watch batteries. The unit could then be attached to the collar in place of the conventional bell. It would, of course, spell the end of the cat's days as a mouser! (K. F., Albion Park Rail, NSW).

• We don't think a warning device to prevent cats from catching birds would work. While ultrasonics can be used with great effect to deter cats and dogs from entering an area, we have no evidence that ultrasonics affects birds at all.

We also think that fitting a cat with such a device would be cruel. In our opinion, cats should not be put out at night, otherwise they will definitely slaughter native animals and birds. Of course, cats kill birds, lizards, etc at any time of the day and so people should probably think twice about having a cat in the first place.

Digital display for Geiger counter

Having recently completed the Geiger Counter published in your October 1995 issue, I wonder if others feel as I do that some analog or digital measuring system registering the counts/second would improve its versatility and interest? I suggest that, using the chart on page 16, it would be best calibrated in rads/hour. (N. A., Hamilton, Qld).

• We plan to publish a modified circuit from one of our contributors in the "Circuit Notebook" pages of the coming September issue.

How to solder mask PC boards

Some time ago I purchased a software package, namely EASYPC, for the fabrication of PC boards. It has proved to be tremendous but in the program there is provision for the laying down of a solder-resist mask.

Could you please advise if there is a photo sensitive, proprietary product, that allows one to lay down the solder resist mask, in the same manner as the tracks are laid down? The drilling of such circuit boards is, to say the least, irksome and whilst there is a drilling program within EASYPC, it requires a numerically controlled drill to implement it.

Would it be possible to run such a project? I'm sure that there are others such as I, who like to design and manufacture their own boards. (N. B., Townsville, Qld).

• As far as we know, solder masks are applied to finished PC boards by a silk-screen process. Component overlays are printed by the same process. We don't know of any photo-sensitive product. However, perhaps one of our readers may know of a product.

Tone controls for a guitar amplifier

I was recently given a 300W amplifier kit and I thought I might make a guitar amplifier out of it. I am now looking for a tone control circuit consisting of treble, middle, bass, gain master volume and many other special items before I start building the amplifier.

I am also looking for circuit diagrams for a distortion foot pedal. Other circuit diagrams for foot pedals such as the "Flanger" would also be greatly appreciated. Could you give me some advice about a suitable loudspeaker as well? (X. Z., Punchbowl, NSW).

• We have published two projects which are relevant to your request: a five band equaliser in December 1995 and a digital effects unit in February 1995. In addition, we published a three-band tone control (circuit only) in the Circuit Notebook pages of the February 1991 issue. We can supply any of these back issues for $7 each, including postage. SC

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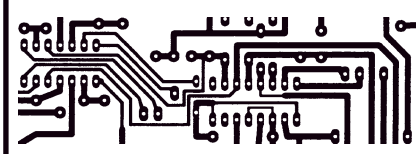

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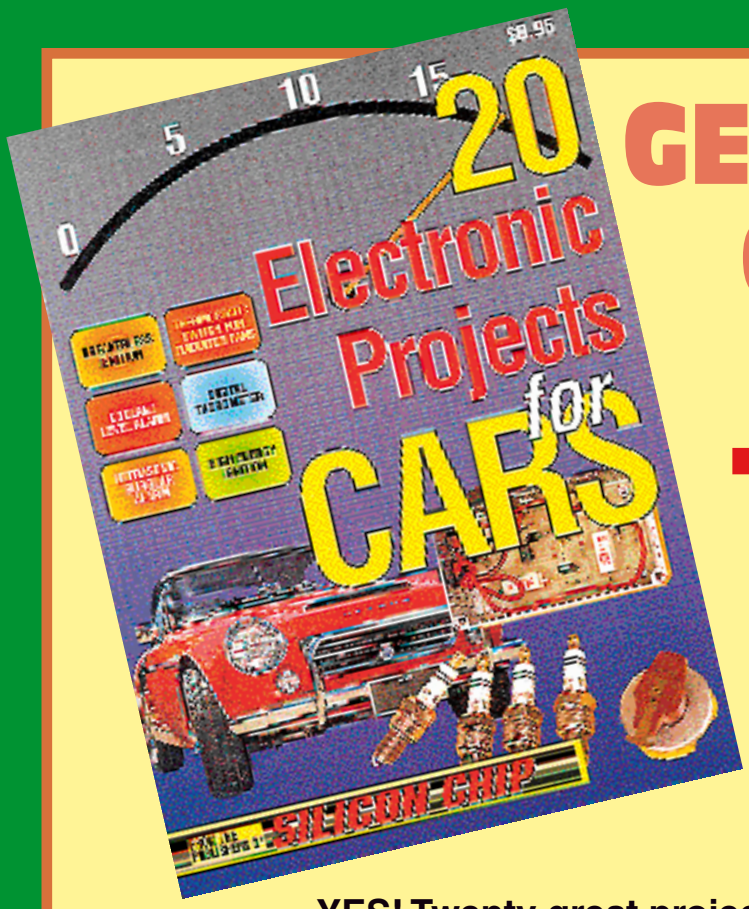

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